

Changing Role of the Buffalo in the New Millennium in Asia



Proceedings of the
Third Asian Buffalo Congress
27-31 March 2000, Kandy, Sri Lanka

Changing Role of the Buffalo in the New Millennium in Asia

***Proceedings of the Third Asian Buffalo Congress of the Asian Buffalo
Association***

Organized by the
Sri Lanka Veterinary Association

In collaboration with the
Ministry of Livestock Development and Estate Infrastructure
Sri Lanka Association of Animal Production
Department of Animal Production and Health
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*27-31 March, 2000
Kandy, Sri Lanka*

Edited by

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PREFACE

In the relatively short period of six years that the Asian Buffalo Association has been in existence, it is indeed creditable for the Association to hold its Third Congress in this part of the developing world where resources for the conduct of international meetings of this nature are scarce. The first Congress was held in Thailand in 1994 and the second took place in the Philippines in 1996. It was at this meeting that the decision was made to hold the Third Congress in Sri Lanka. The Sri Lanka Veterinary Association (SLVA) gladly accepted the invitation by the Asian Buffalo Association (ABA) to host and organise the meeting on behalf of the ABA. Indeed, the SLVA was ably supported in this endeavour by many other organisations and institutions, such as the Sri Lanka Association for Animal Production, Ministry of Livestock Development and Estate Infrastructure, Department of Animal Production and Health, National Science Foundation and the University of Peradeniya.

The main objectives of the Third Congress were (1) to review the present knowledge on water buffalo production in Asian, South America and the Mediterranean regions, (2) to examine the changing role of the water buffalo in Asian farming systems and prospects for the future and (3) to examine the scope for the more efficient utilisation of the buffalo in the context of the changing needs and socio-economic conditions.

The Congress was attended by 21 foreign participants representing most of the countries in Asia as well as some European countries, where buffalo farming is a popular livestock enterprise. A large proportion of the participants (126) were from Sri Lanka and included animal scientists, policy makers, farm managers, administrators and veterinarians.

The scientific papers included in these Proceedings are arranged under the relevant subject headings of the Plenary Sessions and Symposia. Papers presented at the Plenary Sessions deal with broad issues related to the buffalo industry, while those presented at the Symposia deal with specific disciplines/subject areas. Keynote addresses by eminent researchers preceded the scientific presentations at the symposia, which highlighted the recent advances within the subject area or discipline. The discussions at plenary sessions and symposia are succinctly presented in order to provide the reader with complete recording of the events of the Congress.

The final section of the Proceedings contains the Conclusions and Recommendations. These in essence is a distillation of the major issues that participants agreed should be addressed by world/regional organisations and/or respective governments in the formulation of research and development strategies to enhance the efficiency of utilisation of the national resources to increase buffalo production in the Asian region.

A field excursion and a workshop were included in the Congress programme to provide an opportunity for greater interaction and fellowship between participants. The overseas guests were provided an opportunity to visit buffalo farms. This was followed by a guided tour to the famous rock fortress at Sigirya. The local participants attended a workshop away from the Congress venue at Kandalama. The workshop provided a forum for some of the overseas and Sri Lankan scientists to focus on topics in buffalo farming which had direct relevance to the day-to-day work of local participants.

An author index is included to help readers to have easy access to the material. In conformity with the standard format of Congress proceedings, a complete list of participants and addresses is also provided.

On behalf of the Organising Committee, we wish to thank the Asian Buffalo Association, Ministry of Livestock Development and Estate Infrastructure, Sri Lanka Association of Animal Production, Department of Animal Production and Health, National Science Foundation of Sri

Lanka and the University of Peradeniya, for their support in organising the Congress. We thank the invited speakers, both local and foreign, for sharing their experiences and expertise at the Congress. A cursory glance through the contents will provide the reader a glimpse of the diversity of papers presented at the Congress

We also thank Agro-Enterprises Limited (AgEnt) for sponsoring the field tour and the workshop and Kiriya Milk Industries Ltd for providing media publicity to the Congress. Finally, we wish to express our sincere gratitude to Ms. Ayesha Banadara and Janaka Herath for their commitment and dedication in attending to the arduous task of typesetting the manuscripts and preparing the final document for printing. We thank the National Science Foundation of Sri Lanka for undertaking the publication of these Proceedings.

J. A. de S. Siriwardene
D. H. A. Subasinghe
N. U. Horadagoda
H. Abeygunawardena

October, 2000

CONTENTS

Preface	iii
Inauguration	
Addresses by	
Dr. Neil Horadagoda Chairman, Organizing Committee	ix
Dr. L.C. Cruz, President, Asian Buffalo Association	xi
Dr. P. Ramanujam, Secretary, Ministry of Livestock Development and Estate Infrastructure	xiii
Prof. K. Dahanayake, Chairman, National Science Foundation	xv
Prof. R.L.H. Gunawardana, Vice Chancellor, University of Peradeniya	xvii
Hon. A. Thondaman, Minister of Livestock Development and Estate Infrastructure	xix
Vote of Thanks – Dr. H. Abeygunawardena, Co-Chairman, Organizing Committee	xxi
Plenary I – Review of Buffalo Production Systems	
Buffalo Production Systems of Asia: An Overview <i>C. Chantalakhana and P. Skunmun</i>	17
Buffalo Production Systems in the Mediterranean Region and Latin America <i>A. Alexiev</i>	25
Comparative Advantage of the Buffalo over Dairy Cattle in the Asian Farming Systems <i>A.A.J. Rajaratne und S.S.E. Ranawana</i>	33
Discussion	33
Plenary II – Buffalo as a Multi-purpose Animal within the Farming Systems of Asia	
Buffalo Milk: Processing and Product Development in Mediterranean Countries <i>A. Borghese, B. Moiola and C. Tripaldi</i>	47
Buffalo Meat Production and Processing: Recent Developments <i>S.K. Runjhan</i>	55
Haemorrhagic Septicaemia: Current Status in the Asian Region and Strategies for Future Control <i>M.C.L. de Alwis</i>	63
Buffalo as a Draught Animal within Smallholder Farming Systems in Asia <i>Pakapun Skunmun</i>	73
Discussion	73
Plenary III – Country Papers	
The Current Situation of Buffalo Production in India <i>S. K. Ranjhan</i>	81
Buffalo Production in Malaysia <i>M. R. Jainudeen and M. Wan Zahari</i>	85
Carabao Industry situation in the Philippines <i>A.N. Del Barrio, D.H. Duran, C.B. Salces and L.C. Cruz</i>	93
The Current Status of Buffalo Production in Sri Lanka <i>B. H. W. M. U. S. Bandara</i>	

The Current Status of Buffalo Production in Thailand <i>Pakapun Skunmun</i>	99
Buffalo Production Research and Development in Vietnam <i>Nguyen van Thu</i>	105
Discussion	117
Plenary IV – Vision for the New Millennium	
Biotechnology: Future Role in Buffalo Production and Health <i>M.R. Jainudeen,</i>	121
Discussion	127
Symposium I - Genetics and Breeding	
Keynote Address: Genetic Improvement of Buffaloes in Asia with Special Reference to Sri Lanka <i>C.M.B.Dematawewa and G.L.L.P. Silva</i>	129
Cytogenetics of Indigenous Domestic Buffalo in Sri Lanka: Current Status <i>P. Abeynayake</i>	143
Crossbred Buffaloes: Their Adaptability in the Dry zone of Sri Lanka <i>A.D.N. Chandrasiri and D.M. Paranagama</i>	147
Discussion	155
Symposium II - Nutrition	
Keynote Address: Technologies for Improving Buffalo Nutrition in the New Millennium: Trends and Prospects <i>M C.N. Jayasuriya</i>	157
Keynote Address: Some Recent Developments in Evaluation and Utilisation of Unconventional Feed Resources <i>Harinder P.S. Makkar</i>	167
Response to Multi-nutrient Supplementation in Nili Ravi Buffalo and Sahiwal Cattle under Semi-Intensive Management in the Dry Zone of Sri Lanka <i>E.R.K. Perera and A.N.F. Perera</i>	183
Buffalo Milk Production by Small, Medium and Large Farmers and their Response to Different Innovations in Punjab (Pakistan) <i>S. H. Raza, A. Ullah, S. Khan and N. Teufel</i>	191
Straw and Fodder Based Supplementation for Buffaloes <i>Sujatha Premaratne</i>	197
Detoxification of Cassava Foliage and its Utilization as a Water Buffalo Feed <i>C.B. Salces, B.A. Hingpit, D.B. Roxas, E.M. Lustria, S.S. Capitan, I.M. Pabuayon and F.E. Merca</i>	209
Oil Palm By-products and Urea Molasses Mineral Blocks as Feed Resources for Buffaloes in Malaysia <i>M Wan Zahari, O.M. Ariff, I. Mohd. Sukri, A. Oshibe and H. Hayakawa</i>	219
Discussion	225

Symposium III - Reproduction

Keynote Address: Modern Reproductive Technologies: Their Potential Application for Improving Buffalo Production in Asia <i>B.M.A. Oswin Perera</i>	227
histological changes in Endometrium during Follicular and Luteal Phases in Water Buffalo (<i>Bubalus bubalis</i>) <i>N. Alboghobeish</i>	237
Performance of Imported Nili Ravi Buffaloes in Sri Lanka in Relation to Environmental Parameters <i>E.R.K. Perera and A.N.F. Perera</i>	241
Discussion	253

Symposium IV - Health

Keynote Address: Viral Infections of Buffaloes - Rotaviruses and Herpesviruses <i>N.P. Sunil-Chandra</i>	255
Prevalence of Cryptosporidium Infection in Buffalo Calves in the Northwestern Province of Sri Lanka <i>R.P.V.J., Rajapakse, N.U., Horadagoda, F. Noordeen, J.A., Jude and A.C.M. Faizal</i>	263
Clinical and Pathological Changes in Buffaloes following Intravenous Inoculation of Endotoxin Extracted from <i>Pasteurella multocida</i> type 6:2 <i>N.U. Horadagoda, T.G. Wijewardana, S.S. Gallage, S.A. Thalagoda and P.D. Eckershall</i>	267
Attempts to Activate 'Latent' Carriers of Haemorrhagic Septicaemia in Buffalo Calves <i>P. Aheynuyake, T. G. Wijewardana and A. A. Vipulasiri</i>	273
Mastitis, Brucellosis and Rinderpest in Buffaloes in Sri Lanka: A Comparison with Cattle <i>I.D. Silva, A. Dangolla and K. Kulachelvy</i>	277
Medetomidine as a Sedative in Buffalo Calves <i>A.B. Kalhor, S.K. Shahani, I.H. Kathio, A.B. Kachiwal and A.Q. Memon</i>	283
Physiological Effects of Medetomidine in Buffalo Calves <i>A.B. Kalhor, S.K. Shahani, A.B. Kachiwal, I.H. Kathio, A.Q. Memon and S.A. Soomro</i>	291
Discussion	297

Symposium V - Biotechnology

Keynote Address: The Application of Biotechnology in Improving the Productivity of the Buffalo <i>A.K. Misra</i>	299
Optimization of Rabbit Peritoneal Fluid and Buffalo Follicular Fluid Concentration for <i>in vitro</i> Maturation, Fertilization and Cleavage of Buffalo Oocytes <i>R. L. Kundu, O. P. Dhanda and S. Singh</i>	325
Cryopreservation of <i>in vitro</i> Produced Swamp Buffalo Blastocysts by Vitrification method using Ethylene Glycol-based Solution <i>P.B. Pedro, D.H. Duran, F.P. Aquino, R. De Vera, M. Masahiko, R.H. Hufana, A. del Barrio, C.B. Salces and L.C. Cruz</i>	331
Discussion	335

Symposium VI - Production Systems

A Survey on Buffalo Rearing Practices in the Matara District <i>T. Seresinhe and K.K. Pathirana</i>	337
Preliminary Survey and Study on Up-country Dry Zone Buffaloes <i>T.S.P. Jayaweera, M.D.M.L.D.K. Yatawara and A.W.A.S. Abeysekera</i>	347
Status of Wild Buffaloes in National Parks and their Adverse Effects on Habitat Management <i>N. Atapattu and V. Perera</i>	353
A Historical Review of the Use and Management of the Water Buffalo in Sri Lanka <i>A.N.F. Perera, S.N. Wickremaratne and E.R.K. Perera</i>	359
Changing Role of the Water Buffalo in the Sri Lankan Agrarian Economy <i>Anura B. Premasundara and H. Abeygunawardena</i>	367
Discussion	381

Symposium VII - Product Technology and Economics

Household Consumption Patterns of Milk and Milk products and Meat and Meat Products (buffalo and cow) and Policy Implications: A Case Study in the Coconut Triangle of Sri Lanka <i>C. Bogahawatte and D.M.S.K. Chandrasekera</i>	383
Effect of Farm and Herd Size on Economics of Buffalo Milk Production in Central Punjab, Pakistan <i>S.H. Raza, A. Ullah, S. Khan and N. Teufel</i>	393
Evaluation of the Keeping Quality of Buffalo Milk <i>Ajantha Horadagoda, D. Welagedara and P.S. Fernando</i>	397
Selection of Lactic Starter Organisms and Permitted Preservatives for Curd <i>P.S. Fernando, N. Kalyanasundaram, A.A. Vipulasiri and T.G. Wijewardana</i>	403
Discussion	409

Congress Workshop

Conclusions and Recommendations

Closing Session

Address by R.O.B. Wijesekera	417
Author Index	421
List of Participants	423
Congress Committees	429
Epilogue - The Buffalo <i>N. Sandaratne</i>	431

Welcome Address by Dr. N.U. Horadagoda

Chairman, Organizing Committee and President Sri Lanka Veterinary Association

Honorable Minister A. Thondaman, Dr. P. Ramanujam, Professor Leslie Gunawardana, Dr. Kapila Dahanayake, Dr. L. Cruz, distinguished keynote speakers, guests, participants, ladies and gentlemen.

On behalf of the Organising Committee and the Sri Lanka Veterinary Association, it is indeed a great privilege and pleasure to welcome you most cordially to the inauguration of the Third Asian Buffalo Congress. Minister Sir, we are indeed happy that you have decided to be here despite a very busy schedule of activities. Your presence signifies your commitment to the livestock industry and its improvement. Dr. Ramanujam, we have in you a person deeply interested in research and always prepared to give a hearing to new ideas and innovations that would increase livestock production. Your participation is a source of strength to the organisers. Your presence Professor Leslie Gunawardana, is an encouragement to many of us who are attached to the University of Peradeniya where the buffalo is a subject of research in several faculties. The association between National Science Foundation and the buffalo research programme is indeed a very long one and your presence Dr. Kapila Dahanayake epitomizes that cordiality and bonding we had over the last several years. Dr. Cruz, President of the Asian Buffalo Association, I warmly welcome you to our midst and your presence is indeed a great source of satisfaction to the organisers of the Congress. I welcome all the foreign and local speakers who have spared their time from their busy schedules to share their knowledge and experiences with the participants at this Congress. A warm welcome is also extended to all guests who have joined us here at the inauguration of this Congress.

I consider it relevant to trace the history of buffalo research in Sri Lanka, at least in brief. The buffalo was indeed a neglected domestic animal in the Sri Lankan research agenda, despite its contribution to the rural economy and ability to thrive relatively well under harsh environmental conditions. Researchers found it extremely difficult to find the funds to carry out investigations to further improve its utilization, but the situation changed in the late 1970s when several international funding agencies showed interest in the research and development activities related to the buffalo. Among the many donors, special mention must be made of the financial support provided by the Swedish Agency for Research Cooperation with Developing Countries (SAREC) now referred to as Sida. The funding was extended over three phases over a period of 20 years and was channelled through the National Science Foundation. The first two phases afforded an excellent opportunity for research, particularly through a multi-disciplinary approach in research. It also provided funding for the development of management packages to suit the needs of the changing livestock practices in the country. The third phase, which concluded last year was aimed at the dissemination of information to the farming community, extension workers and to others engaged in livestock production and health activities.

The buffalo research programme was actively supported by governmental and non-governmental organisations responsible for livestock production in Sri Lanka. In this context, a pivotal role was played by the institutions under the Ministry of Livestock Development and Estate Infrastructure, the Department of Animal production and Health (DAPH), the Veterinary Research Institute (VRI), the National Livestock Development Board (NLDB) to name a few. The Universities, particularly the University of Peradeniya made a significant contribution towards the success of the buffalo research programme in Sri Lanka. Indeed the funding from the research programme helped the development of the infrastructure of the organizations collaborating with the project. I believe, that it is in recognition of the output by the scientists and the commitment of the government to develop buffalo production, that the Asian Buffalo Association afforded the opportunity to Sri Lanka to host the Third Asian Buffalo Congress.

In conclusion, I hope that the Congress will provide an ideal opportunity for exchange of ideas, updating of knowledge as well as for social interaction and fellowship. I also hope the Congress will be able to take stock of the current trends, developments and research in buffalo farming and make recommendations that will direct the future planning for the further utilization of the buffalo in the Asian region. I wish to thank you all for the patient hearing and wish our guests, especially those from overseas and those outside this city a very pleasant and memorable stay in Kandy.

Address by Dr. L. Cruz

President, Asian Buffalo Association, Manila, Philippines

Hon. Mr. Thondaman, Dr. Ramanujam, Secretary, Ministry of Livestock Development, Prof. Leslie Gunawardena, Vice-chancellor, University of Peradeniya, Prof. Kapila Dahanayake, Chairman, National Science Foundation, Dr. Neeli Horadagoda, Chairman of the Congress Organising Committee, Dr. H. Abeygunawardena, 20-Chairman of the Organising Committee, Dr. J.A. de S. Siriwardene, Congress Coordinator, Dr. D.H.P. Subasinghe Congress Co-coordinator, the many scientists and ladies and gentlemen, a very good morning to everyone.

On behalf of the Asian Buffalo Association, I would like to express our gratitude to the Organising Committee of the Congress and the important hosts, the Sri Lanka Veterinary Association and the Sri Lanka Association of Animal Production. I feel overwhelmed by the preparation that has been made by the Organising Committee and the effort and time put in by the Organising Committee during the past year. The decision to hold the Third Asian Buffalo Congress in Sri Lanka was a very good decision.

The Asian Buffalo Association (ABA) was established in 1994, after the establishment of the International Buffalo Federation, which supposedly gathers all scientists from around the world. One of the founding fathers of the ABA was Prof. A. Alexiev, who is right here today. In 1994, the Asian group recognizing that 36 percent of the buffaloes are in Asia and that most of the genetic material for the development of the buffalo is to be found in Asia, decided to form the Asian Buffalo Association. The first Asian Buffalo Congress was held in Thailand in 1994, followed by the second Congress in Manila, Philippines in 1996. It was on that occasion that it was decided to hold the third Congress in Sri Lanka.

The ABA's main objective is to put together a mechanism by which the scientists in the Asian region can interact and share information and knowledge among themselves and make a definite decision on how to utilize this important animal resource in this region.

We recognise the differences in the buffalo production systems in Asia, which is poor farmer based, as against the emerging production systems in the other parts of the world, such as the South America. For this reason, the Asian scientists believe that we must put together our efforts and steer the development of the poor farming sector.

Finally, I want to express again my deep appreciation to the Organising Committee for organising this very wonderful Buffalo Congress.

Address by Dr. P. Ramanujam

Secretary, Ministry of Livestock Development and Estate Infrastructure

Hon. Minister of Livestock Development, President of the Sri Lanka Veterinary Association, President of the Asian Buffalo Association, Vice Chancellor of the University of Peradeniya, Chairman of the National Science Foundation, distinguished foreign and local delegates. It gives me great pleasure on behalf of the Ministry of Livestock Development and Estate Infrastructure to be able to co-sponsor the Third Asian Buffalo Congress. As the Chairman of the Organising Committee mentioned, the buffalo has been considered a neglected animal in respect of scientific attention. However, recently the buffalo has been subjected to intense focus by research scientists in the Asian region, especially during the last two decades. Thus the situation has changed, both in Sri Lanka as well as in the neighbouring countries, with the flurry of research in a number of agencies and countries. In Sri Lanka the IAEA and SAREC have provided funds generously for research on the indigenous buffalo. Today's meeting is an important occasion, where scientists from several countries and experts both local and foreign have gathered to discuss issues pertaining to the development of this animal. The buffalo is an important animal in the tropical countries.

I am informed that of the world population of 130 million, 124 million, almost 95% are found in Asia. Half of this population, about 64 million is found in India. Pakistan also has about 12 million. In India, which is the World's No. 2 milk producer, about 50% of the milk come from the buffalo. The situation is the same in Pakistan and Bangladesh. So the buffalo is an important animal in South Asia as well as in South East Asian countries. Pakistan, Bangladesh, Thailand, Indonesia, the Philippines, Burma, Vietnam and Laos, etc. are countries having large populations of buffaloes. Sri Lanka comparatively has a very small population of 727,700 buffaloes that is spread around most parts of the country, associated with activities connected with paddy cultivation. Like in other countries, the buffalo in Sri Lanka is used for draught, milk, meat and other purposes, in addition to their value in providing manure, skins etc. The advent of mechanisation in agriculture has pushed the buffalo to a corner, as regards its use as a draught animal. But the largest interest is in the use of the buffalo for milk. The buffalo is an extremely valuable animal to the country. These are owned predominantly by small scale farmers and therefore it is important to use the buffalo for income generation by developing the animal for meat and milk production. The situation I presume is the same in all the countries represented here.

Since India and Pakistan have the largest population of buffaloes, these countries have developed as the leading countries in buffalo breeding and research and development. Due to this, a number of dairy buffalo breeds such as the Murrah, Surti, Nili Ravi and some other such breeds that I have heard of, are available in these countries. Artificial breeding is extensively practised in these countries, while in Sri Lanka it is yet to be realised. The average milk production has been increasing annually in these countries. We therefore have much to learn from these countries.

In this regard, this is an ideal opportunity to learn from each other and exchange information. I am sure, this opportunity will be utilised to the maximum by the delegates and participants. Though I am not a livestock man, I am aware of the progress of the buffalo industry in the world as well as in Sri Lanka. I have also met researchers and scientists who have been working in this field for a long time. Today, I presume I will meet more such experts from all over the world.

I have heard that a regional data bank has been established in Thailand. In Sri Lanka too I am proud to note that a considerable amount of scientific research has been done with respect to this animal. Yet, the buffalo in Sri Lanka literally has remained a buffalo. What I mean, is that the benefits of research have not gone to the field to make an impact. Sri Lanka has a very small population of river type buffaloes. The population of crossbreds too is hardly noticeable, there

being over 90% of the indigenous swamp type. Of the estimated 342 million litres of milk produced in 1998 in Sri Lanka, 85 million, about 24% came from the buffalo. However, the amount of buffalo milk reaching the formal market is rather low, indicating that the bulk of the buffalo milk goes into the production of milk products, predominantly curd, which is a popular local milk product.

My Ministry will be very much interested in the recommendations of the Congress. While you discuss general issues on the development of the buffalo as an economic animal, I hope you will make country specific recommendations as well. I am happy to see the buffalo development project with assistance of the National Science Foundation has joined hands with the SLVA and the Ministry to host this regional Congress in Sri Lanka. I am aware that it is not easy to organise an international meeting of this nature. It needs a considerable amount of planning, devotion and hard work. Therefore I wish to express my sincere appreciation to the relevant officers who have rallied together to organise this important event.

To the foreign guests, resource persons and participants, I wish to extend a warm welcome to Sri Lanka. Sri Lanka has a lot to offer, having a reputed traditional rich culture, warm hospitality and scenic beauty. I trust that the project staff and organisers have made some effort to show you a glimpse of the scenic beauty and some of the historic sites. You are now staying in Kandy, the hill capital of Sri Lanka. Kandy is a very picturesque place and it is worth while having a look around during the next 3 days. I am sure that the project will take care of you and give you a taste of Sri Lankan hospitality. I am sure that all of you, when you go back home will carry back not only the knowledge about the buffalo, but also a taste of Sri Lankan beauty, culture and hospitality. I wish all of you a pleasant stay in Kandy.

Address by Dr. K. Dahanayake

Chairman, National Science Foundation, Colombo

Hon. A. Thondaman, Minister of Livestock Development and Estate Infrastructure, Prof. Leslie Gunawardena, Vice Chancellor, University of Peradeniya, Dr. P. Ramanujam, Secretary of the Ministry of Livestock Development and Estate Infrastructure, Dr. Neil Horadagoda, Chairman, Congress Organising Committee, Dr. Cruz, President of the Asian Buffalo Association, invitees, foreign delegates, ladies and gentlemen.

As chairman of the National Science foundation, which is the successor of the former Natural Resources, Energy and Science Authority of Sri Lanka, I am pleased to be associated with the Third Asian Buffalo Congress. This Congress can be considered as the crowning moment of nearly 20 years of research efforts by Sri Lankan scientists on the buffalo, an animal that can survive under very harsh environmental conditions and poor feeds. This is an animal that provides livelihood to hundreds and thousands of peasants and rural farmers in Sri Lanka and the Asian region.

Ladies and Gentlemen, in the mid-1970's SAREC, the Swedish Agency for Research Cooperation with Developing Countries indicated an interest to support a research programme on the buffalo. In 1980, a workshop was held, to which SAREC invited interested scientists from various institutions in Sri Lanka. As an outcome of this workshop, a multi-disciplinary research project was initiated in 1983, largely supported by SAREC, with NAKESA functioning as the local coordinator and administrator. During the past two decades, leading local veterinarians had been at the helm of the activities of the buffalo research and development project, namely Dr. B.M.A.O Perera, Dr. J.A. de S. Siriwardene, Dr. S.S.E. Ranawana and presently Dr. H. Abeygunawardena of the Faculty of Veterinary Medicine and Animal Science.

The National Science Foundation is proud to note that since the initiation of the project in 1983, 23 publications have resulted from the research work conducted by the project. These provide information on the physiology, nutrition, reproduction and management of the buffalo. The benefits of these research activities have reached the farmers, the extension workers, Veterinary undergraduates and post-graduate scientists. For the farmers, several leaflets have been produced and also a training manual for extension workers. In addition, a Handbook for Veterinarians and also a four-volume publication was undertaken by the National Science Foundation and already the volume on Health has been published and is available. I understand that a basket of technologies is now available to farmers who are the end-users of the research. These farmers can select new and appropriate technologies that will suit their needs. These relate to all aspects of feeding, management, reproduction and health.

On behalf of the National Science Foundation, I congratulate the research scientists for their research achievements and technological developments through the research and development project over the last two decades. It is gratifying to note that the end-user has benefited from this research and I am sure that today's Congress will deliberate on these findings and this will provide an occasion for the exchange of information among the scientists of the region. The deliberations of this Congress will, I am sure help to popularise buffalo rearing and eventually lead to the improvement of animal production and health and thereby improve the lot of the rural farmer not only in Sri Lanka but also in all parts of the Asian region. I take this opportunity to thank the Asian Buffalo Association for selecting Sri Lanka as the venue of this Congress. This will give an opportunity to highlight the advances in research and generate a useful exchange of ideas. Finally, I thank the organising Committee for inviting me to address this important congress and I wish the congress all success. Thank you.

Address by Professor R.L.H. Gunawardana

Vice-Chancellor, University of Peradeniya, Peradeniya.

Mr. Chairman, Hon. A. Thondaman, Minister of Livestock Development and Estate Infrastructure, Dr. Ramanujam, Secretary, Ministry of Livestock Development and Estate Infrastructure, Dr. Kapila Dahanayake, Chairman, National Science Foundation, Distinguished Guests, Ladies and Gentlemen, I wish you a Very Good Morning !

I am extremely thankful to the organizers of this important Congress for inviting me to speak to you at this inaugural ceremony. There are several reasons why I am pleased to be here with you today. A review of the progress that has been made in the South Asian region during the past three decades or so would generally yield considerable satisfaction over what has been achieved. However, such a review would also reveal that there are certain areas that are yet stagnant, and are marked by a striking lack of dynamism. I refer in particular to peasant production and some of the significant problems confronting our future plans for development in the rural sector lie there. This is one of the main reasons why this Congress and the results of research work to be presented by the scientists who are here will be of immense importance and relevance.

Your work is related to improvement of productivity, improvement of family incomes and the improvement of the living conditions of one of the most vital sections of the population which includes within itself a large segment of the poorest of the poor. These are people who do not see very much hope despite the noteworthy economic development that is taking place. I have always believed that centres of excellence in research, while striving to reach the highest levels and standards of research, should also make a deliberate attempt to focus on the problems of the poverty-ridden areas in Asia. I have also said on several occasions that these are not the responsibilities only of the scientists living in those particular countries. The alleviation of poverty necessitates and calls for a truly global effort. There is a tremendous need to realise that research efforts by scientists in this regard should be joint efforts that span across geographical, political and cultural boundaries. Scientists have to necessarily pool their information from different territorial units and work together as teams. I think this highlights one of the features of this Congress, which I greatly admire. As Dr. Ramanujam pointed out, even though the problem of improving the productivity of the buffalo could be thought of as an Asian problem, it is not only the Asian scientists who should be working on this important problem. As would be expected, scientists in India and Sri Lanka, which are countries where the buffalo population is extremely important to their economies, have been working together with colleagues in Southeast Asian lands, such as Thailand, Philippines and Vietnam, which also have significant numbers of buffaloes, in order to form linkages and to exchange ideas on this important problem. It is particularly gratifying to note that the meeting being inaugurated today also represents a combination of research efforts of two countries in Europe, namely Italy and Bulgaria.

As the Vice-Chancellor of the University of Peradeniya, I wish to bring to your notice that our University has been quite interested in the recent past in extending its academic links. I am particularly happy to note that the University of Peradeniya is a research centre, where quite a few scientists are focusing on problems related to the improvement of productivity of the buffalo. They are working together with scientists affiliated to diverse organizations within this country, while being funded by donor organizations within and outside this country. This Congress gives them an opportunity to extend their intellectual links. This is something that I am sure would help cross-fertilization in research and contribute to further improve the quality of their work. The University of Peradeniya will be happy to continue and foster such collaborative efforts.

The third point I hope to emphasize is that the buffalo has been known for a very long time in the history of South and Southeast Asia. In fact, the buffalo figures prominently in some ancient

Address by Hon. A. Thondaman

Minister of Livestock Development and Estate Infrastructure

President, Sri Lanka Veterinary Association, President, Asian Buffalo Association, Vice Chancellor, University of Peradeniya, Chairman, National Science Foundation, foreign and local participant, Ladies and gentlemen.

Let me first of all thank the Organising Committee and the President of the Sri Lanka Veterinary Association for inviting me here as Chief Guest to the opening of the Third Asian Buffalo congress. I am made to understand that most of the countries in the regions are represented here by scientists who have performed valuable research in various aspects of this important animal, the water buffalo. In addition, scientists from other countries too have also come to exchange information they have generated in the recent past. I trust that this Congress will be a fruitful one and will achieve all the goals and objectives planned by the organising committee. The water buffalo was recognized officially when a Swedish scientist called it *Bubalus bubalis*. Since then the buffalo has been existing in the world. Asia has 95% of the world buffalo population. I am also aware that in countries of the South Asian region, the buffalo is extensively used for milk production. Though the buffalo is named as a triple purpose animal, in the Asian countries, the animal is actually a multipurpose animal. It is used not only for draught, milk and meat, but also for various other activities. Thus the buffalo has become an economically extremely important and valuable animal in Sri Lanka. In Sri Lanka, the buffalo has been used extensively for paddy cultivation. That is the reason why the highest population is found in places like Kurunegala, Ampara, Batticaloa, etc. This is why the animal cannot be seen in the hill country plantation areas and in the northern peninsula. Evidence from the earlier period of hydraulic civilization in the dry zone of Sri Lanka indicates the economic and social significance of cattle and buffaloes and their by-products. Though the buffalo is still used extensively for the preparation of paddy fields and activities related to paddy harvesting, in Sri Lanka, certain pockets of milk production have developed in certain parts of Ruhuna, the East and Wayamba. Buffalo milk production is a lucrative business. There are also a few urban dairies that specialize in buffalo milk production. The buffalo milk is mostly converted to a local dairy product called curd, which is a delicacy in Sri Lanka. Though the buffalo has been an important animal economically as well as socially, very little attention has been given to use this animal to its full potential. In Sri Lanka the indigenous buffalo accounts for nearly 95% of the total population, which is about 0.73 million. Breeding programmes are rather limited, while management situations are still primitive. I also understand that this has been a long neglected animal not only in Sri Lanka but also in most parts of Asia. However, I am glad that recently much research attention has been given to this animal. International organizations have been generous in their attempts to develop the water buffalo and the local scientists who have made full use of these investments to launch a large number of scientific investigations on this animal. Since this is the third time that scientists have met in an international forum, I believe a large amount of information must be available about the buffalo, to exchange between the participants. What I would like is to see that this information is used to develop the buffalo in Sri Lanka as well as in other countries. The results of these scientific investigations must reach the farmers. For this, the recommendations must be practical and economical. Unless this is not done, this Congress becomes a mere theory. I am personally interested to know how we can develop the buffalo in Sri Lanka. My Ministry will give full priority to such recommendations of the Congress. Finally, I extend my best wishes for the successful deliberations and a pleasant stay in Sri Lanka.

Vote of Thanks by

Dr. H. Abeygunawardena

Co-Chairman, Congress Organizing Committee

Hon. Minister, distinguished guests, ladies and gentleman, it is my pleasure to propose a vote of thanks on behalf of the organizing committee of the 3rd Asian Buffalo Congress.

Mr. Arumugam Thondaman, the Honourable Minister of Livestock Development and Estate Infrastructure, we are most grateful to you Sir, for accepting our invitation and for being with us to grace this occasion amidst a very busy schedule. Dr. P.Ramanujam, the Secretary of the Ministry of Livestock Development and Estate Infrastructure, we wish to thank you Sir, for being receptive to all our requests and also for being with us at the inaugural sessions of the Congress. Professor Leslie Gunawardena, the Vice Chancellor of the University of Peradeniya, we are very thankful to you Sir, for being with us at the opening of the Congress and also for extending assistance in various ways in organizing this event. Professor Kapila Dahanayake, the Chairman of the National Science Foundation, we wish to thank you Sir, for the continuation of the assistance in cash and kind towards the research and development efforts on the water buffalo and also for being with us today at the opening sessions of the Congress. I thank Dr. Liberto Cruz, the President of the Asian Buffalo Association, for his presence here today, despite various involvements as the Chairman of the Philippine National Dairy Authority and the Philippine Carabao Centre and also for the generous contribution towards the organization of the 3rd Asian Buffalo Congress here in Sri Lanka. I wish to thank all the special guests and invitees who are present here, for accepting our invitation and for being with us this morning. Your presence is indeed a great source of encouragement and inspiration.

I thank all the invited speakers of the plenary sessions and symposia, both foreign and local, for accepting our invitation to deliver scientific presentations to enrich the deliberations of the Congress and also for their presence here at this inaugural session. I wish to thank all the presenters of the scientific papers at the symposia for their enthusiasm to submit their scientific communications for consideration as presentations at the Congress and also for being with us at this opening session. I also wish to express our sincere appreciation of the interest shown by the local scientists, administrative and planning officers, animal production and health specialists, and development and extension workers for their interest and enthusiasm to take part in this Congress and also for being with us here today. I have no doubt that you will benefit tremendously from the deliberations scheduled for this Congress and also from the workshop that will be held on Thursday, the 30th March at Kandalama.

I wish to acknowledge the cooperation and the financial assistance extended towards the organization of this Congress by the:

- Ministry of Livestock Development and Estate Infrastructure
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Hindu myths. In Sanskrit the buffalo is known by the term *mahisha*. The popular goddess Durga for whom festivals are held all over the Hindu world is referred to as *Mahishasura-mardini-durga*. This title emphasizes her role of "overcoming" or "taming" the buffalo. Ancient sculptures portraying Durga performing this role are to be found in many places in India and Sri Lanka as well as in the lands of Southeast Asia. I think that the emphasis in the myth on the need to "defeat" and to "tame" the buffalo may be perhaps due to the attention that was being paid at the time of the origin of the myths to introduce what was formerly a wild animal to agricultural work. The taming of the buffalo and the harnessing of animal energy, in addition to human energy that was being used up to that time, for agricultural production would have marked an important transitional stage in the history of agriculture in South and Southeast Asia. This would not have been an easy project, since by nature the buffalo is a sluggish animal, not very heedful to human commands. In harnessing buffalo energy humans no doubt faced many problems. Today we know that the objectives had been successfully accomplished, perhaps thanks to Durga!

Looking forward into the 21st century, it is not only the area of the utilization of the buffalo for draught energy that we have to primarily think of. In order to improve the resources of the rural hinterland, in particular, the resources of the poor people in the rural sector, emphasis will have to be placed very heavily on the productivity of the buffalo in milk and meat production. I think some of the papers that will be presented today do focus on problems of economy, problems involved in breeding buffaloes and raising their productivity. All this work will be tremendously useful to each of the Asian countries represented here in helping to develop the rural sector and the poorest segments of the populations of these countries. We look forward with very great interest to recommendations arising from the deliberations of the Congress. Your recommendations will be helpful in the formulation of policies at both national and international levels, and also in making decisions with regard to future research programmes.

I wish the Congress all success and I wish the foreign delegates present here a most pleasant stay in Sri Lanka.

BUFFALO PRODUCTION SYSTEMS OF ASIA: AN OVERVIEW

C. Chantalakhana and P. Skunmun

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Abstract: Water buffaloes (*Bubalus bubalis*) are being raised as economic animals in more than fifty countries in the world, but about 95% of them are to be found in 28 countries in Asia. There are two major breed types of buffalo i.e. the river type and the swamp type. The river type consists of several breeds while the swamp type has practically only one breed. The water buffalo is generally regarded by rural farmers as a multi-purpose animal. However, commonly the river buffaloes are raised for milk production in most countries in South Asia, while the swamp buffaloes are used as draft-and-meat animals in mixed or integrated crop-livestock systems in Southeast Asian countries and South China. Dairy buffaloes are generally raised in three common systems; these are (1) extensive system or integrated with crop production, (2) semi-intensive system, and (3) intensive system. In small-farm mixed crop-livestock systems in rural areas, buffaloes not only provide milk or meat but also draught power, manure, and socio-economic values such as savings, recreation, and food security. Buffaloes, as a component of farming systems, are an important factor contributing to the sustainability of mixed crop-livestock systems. Productive and reproductive performances of buffaloes raised in different systems are presented. Future trends or evolution of buffalo production in mixed crop-livestock farming systems is discussed. It is expected that buffaloes will be used more and more for specialized milk or meat production in Asia, due to population pressure and the rising beef and milk demand in the coming decades.

Keywords: Production systems, river buffalo, swamp buffalo, draught power, milk, meat

Introduction

Approximately 95% of the total number of buffaloes (*Bubalus bubalis*) in the world are found in Asia and Pacific region. During the recent decade (1983-1993) the number of water buffaloes in the world increased slightly by 1.3 per cent per year (FAO, 1994). In 1997, there were approximately 161 million water buffaloes in Asia distributed in 28 countries.

In general, there are two breed types of the water buffaloes; the swamp type and the river type. The swamp buffaloes are raised mainly in China and Southeast Asia. The river buffalo breeds are found mainly in India and Pakistan. The river buffaloes in Europe and the Middle East are commonly referred to as the Mediterranean breeds. Swamp buffaloes are mostly reared by farmers in developing countries as draught animals to provide farm power, manure as fertilizer, and meat. The river buffaloes are raised mainly for milk while some small farmers may use them as draught animals to pull wagons or till farmland. The Mediterranean buffaloes are raised mainly for milk and meat such as those found in Italy, Romania and Yugoslavia.

Buffalo raising in Asia has been traditional among small farmers, who grow crops and livestock for their subsistence. The river buffaloes are raised for milk production both on small-scale and commercial scale, such as those in India and Pakistan. Meat from buffaloes is an important source of protein foods in Asia. Almost half of the beef supply in Thailand is derived from buffaloes. Table 1 shows the distribution of water buffaloes by country; India, China and Pakistan are the top three countries as far as the numbers of buffaloes are concerned.

Water buffaloes are classified into two breed types, the river and swamp, as mentioned in the previous sections. The river buffaloes account for more than 70% of the total buffalo population in the world, while the swamp buffaloes account for almost 30%. The number of breeds of river buffaloes are numerous, but the swamp buffaloes belong to only one breed, within which different strains could be identified within a country population.

Table 1. The distribution of buffalo in Asian countries in 1997

Continent	Country	Number (1,000)	Type of buffaloes
Asia		161,599	
	Azerbaijan	298 F	Mostly river
	Bangladesh	854*	Mostly river
	Bhutan	4 F	Mostly river
	Brunei	4 F	Mostly swamp
	Cambodia	770 F	Swamp
	China	23,518*	Swamp/few river
	Georgia	20 F	River
	India	92,190*	River
	Indonesia	3,140 F	Swamp/few river
	Iran	465*	River
	Iraq	75 F	River
	Kazakhstan	100 F	River
	Laos	1,212 F	Swamp
	Malaysia	150 F	Swamp/some river
	Myanmar	2,297	Swamp/some river
	Nepal	3,362	Mostly River
	Pakistan	22,000 F	River
	Philippines	2,968	Swamp/few river
	Sri Lanka	761 F	River/some swamp
	Syria	2 F	River
	Thailand	4,200 F	Swamp
	Turkey	255 F	River
	Vietnam	2,954 F	Swamp/few river

F = FAO estimate, * Unofficial data

Swamp buffalo

Most swamp buffaloes are dark gray in color, but some are white. The frequency of white buffaloes varies from country to country as well as among locations within each country. The frequency of white buffalo in Thailand ranges from 0 to 15 per cent (Nozawa and Na Phuket, 1974). Black and white buffaloes (piebald) are to be found in South Sulawesi, Sumba and the Sumbawa Islands of Indonesia, but they occur less frequently than gray or white buffaloes (Harjosubroto and Astuti, 1980). As far as colour markings are concerned, a white chevron (sometimes two) below the neck of gray buffaloes is commonly found. Thai farmers regard animals with white stockings on four feet as a good luck sign. Hair whorls are commonly found on various parts of the body, which usually appear on both sides of the shoulder, hip, face, and forehead. In general, the horns are swept-back into semi-circles, but remain on the same plane as the forehead. More details on genetics of swamp buffalo are given in Chantalakhana (1991).

Swamp buffaloes reach a mature weight in about 4-5 years of age. The average mature weights vary from 450 to 650 kg in males and from 350 to 450 kg in females. Table 2 shows the mature weights as well as the body measurements of the swamp buffaloes in different countries.

River buffalo

In general, the breeds of river buffaloes can be classified geographically as follows (Mahadevan, 1992).

- North Indian and Pakistani breeds: These are Murrah, Nili-Ravi, Kundi and Bhadawari. The first three breeds are large and the last is medium in size.
- Central Indian breeds: These are Jafarabadi, Surti, Meshana, Nagpuri, Pandharpuri, Marathwada and Dharwar. Only the first breed is large and the rest are medium in size.

Table 2. Mature weight and size of swamp buffaloes

Countries	Weight (kg)	Height (cm)		Length (cm)		Height girth (cm)	
		Male	Female	Male	Female	Male	Female
China ^{1/}	450-600	136	126	157	151	204	202
China	400-500	129	124	143	132	188	179
Indonesia	450-500	130	125	-	-	-	-
Indonesia ^{2/}	500-600	127	124	-	-	190	180
Malaysia	364-545	129	121	123	121	183	180
Philippines	520	-	125	-	-	-	193
Philippines	364-545	127	120	-	-	196	184
Taiwan	400-500	129	124	141	135	186	190
Thailand	404-600	121-137	121-126	141-148	132-137	186-209	181-183

Source Camoens (1976) and others as listed in the table

^{1/} Liu, (1975)

^{2/} Harjosubroto and Astuti, (1980)

- South Indian breeds: There are two small-size breeds i.e. Toda and Malabari
- Egyptian breeds.
- European breeds.

These riverine breeds are relatively well defined (Bhat, 1992). Most of them are found in India and Pakistan. Commonly, the river buffaloes have curled horns and are easily differentiated from the swamp type. The variation of horn-shapes is found among the river breeds. The best known breeds are Murrah, Nili-Ravi, Jafarabadi, Surti, Mehsana, Nagpuri, Egyptian and European (the Mediterranean).

Although the swamp and the river buffaloes share the same scientific name, the swamp type possesses 48 chromosomes (2n), while the river type has 50. According to Chavananikul (1994), the difference in chromosome number is due to a tandem fusion of the 4th and the 9th pairs of the river type autosomes, to be the first largest pair in the swamp type. Crossbreeding between these two types is possible and produces offspring with 49 chromosomes (F₁). The backcrossing of F₁ crossbreds to the swamp and to the river types can also produce the offspring possessing 48 or 49 chromosomes and 49 or 50 chromosomes, respectively. Recent investigations reveal the occurrence of a meiotic impairment, which affects the semen quality in the crossbred male carrying unbalanced karyotype 49 chromosomes (Bongso *et al.*, 1982; Gustavsson, *et al.*, 1993; Petheram, 1991).

Production Systems and Products

Swamp buffalo production on small farms

Ninety-five to 99% of the swamp buffalo production systems in China and Southeast Asian countries can be classified as smallholder or small farm systems, where buffalo raising is not regarded as a distinct enterprise, but rather is an integral part of the crop production systems (Bunyavejchewin and Chantalakhana, 1991). Swamp buffaloes are primarily a source of farm power for tillage and transportation and a source of manure for fertilizer, while meat and milk are secondary products in these systems. The most common regions where buffaloes play a prominent role are the rice production areas. Swamp buffaloes are commonly used for draught power in lowland rainfed rice production systems, while farm machinery is used in irrigated rice cultivation. Swamp buffaloes whenever available are also used in the cultivation of upland rice and other crops. In China and many countries in Southeast Asia, draught animal power remains an important source of energy input per unit area of cultivated land, in spite of the increasing use of petroleum based power in certain areas. It has been reported that swamp buffaloes provide 20 to

30 per cent of the farm power in South China, Thailand, Indonesia, Malaysia, the Philippines and Indochina (Charitalakhana, 1988).

Swamp buffalo production on small farms under village conditions is an activity, which is complementary to crop production and makes use of non-marketable farm products and marginal lands, utilizing surplus family labour, requiring minimal cash inputs and simple and traditional technology. It is generally a non-market-oriented production activity, that is subject to a relatively low degree of risk.

In general, attention is not given to obtaining a high rate of output of meat from the swamp buffaloes, because other products and services are considered more important in the small-farm systems. The swamp buffalo production systems under village conditions in Southeast Asia is therefore generally referred to as smallholder production systems. In general, the small-farm buffalo husbandry can be described as follows.

In most Southeast Asian countries, village farmers usually set aside small-plots of land for buffaloes and cattle grazing to supplement other grazing land resources available in the village such as paddy field, scrub forests on upland areas, highway shoulders, rice bunds and communal grazing lands. In general, buffaloes depend mainly on rice straw stubble and other crop residues, such as corn stalks, cassava or kenaf leaves, which may also be available as substantial sources of roughage, especially during the dry season.

During the post-harvest season, buffaloes are allowed to graze in the paddy field, where breeding will also take place. Following this in the summer, animal feed in paddy fields becomes scarce and buffaloes have to graze on highway shoulders or in upland scrub forests. At this time the feed from grazing will be supplemented with rice straw or other green fodder. With the onset of the rainy season and the start of the cropping season, most areas will be cultivated with rice or upland crops. Animals will be grazed only in fallow fields or plots set aside for them and will be tethered in or near the homesteads area and fed rice straw. Generally, concentrate or mineral supplements are not given to animals. There are usually no cash inputs, and animals are cared for mostly by family labour, i.e. children, women or old folks. Buffalo breeding generally takes place through random natural mating. Within-breed breeding is commonly practised in swamp buffaloes.

In general, male buffaloes are preferred for work, but due to the shortage of draught animals, both males and females are now used for work. Male buffaloes intended for work are generally castrated at the age of two to two and a half years, depending mainly on size and body condition, before they are trained for work. Farmers select draught animals mainly on the basis of size, height, conformation and other traditional features relating to external appearance, such as horns, locations of hair whorls, chevrons, color and markings.

Castration of work buffalo in the long run, has a negative effect on animal body size since larger animals are prevented from breeding. The shortage of good-quality breeding bulls has also been recognized as a serious problem resulting from castration of buffaloes in rural areas in some countries, such as Thailand. Castration of the males increases the possibility of inbreeding in the village herds.

Selective breeding, except crossbreeding, has not been practised. Rearing of breeding bulls is not practical since the number of breeding cows per holding is very small. As mentioned earlier, village buffalo breeding usually takes place during the post-harvest season when male and female animals in villages are grazed together in the paddy fields, where there is an abundant supply of feed. Random natural mating takes place mostly during this period. Artificial insemination is also used to a very limited extent in some countries. The average annual calf crop among village buffaloes appears to be around 35-40%. Table 3 shows some characteristics of the swamp buffaloes in small farms.

Health care of the swamp buffaloes is minimal. Some may be vaccinated against certain infectious diseases, but most are not. Common infectious diseases in buffaloes are foot-and-mouth disease and haemorrhagic septicaemia. A small percentage of village buffalo cows are found to be positive for brucellosis. In addition, internal parasites, such as strongyloides and neoascaris are commonly found in buffaloes.

The major products and functions of buffaloes, as recognized by farmers are as follows:

Working abilities of the swamp buffaloes

The intensity of work of draught buffaloes varies between locations, seasons and farming systems of various countries. In general, male buffaloes are preferred for work, because of their larger body size, which is believed to be related proportionally to work efficiency. However, due to the increasing shortage of draught animals during the recent decades, both male and female buffaloes have been used for work, including pregnant female buffaloes. Buffaloes with a body weight ranging from 400 to 900 kg can produce draught power equivalent to 0.75 horse-power (Hp) as compared to 1 Hp from a light horse of 400 to 700 kg body weight (Cockrill, 1974). Under normal conditions, buffaloes appear to move at a slower speed, compared to the horse, mule or donkey, but they are very efficient for work in muddy or flooded land such as paddy fields.

In Southeast Asia, for instance in the Philippines, it has been reported that buffaloes of both sexes are used for work on an average of between 80 to 100 days per year (Momongan, 1994). In some villages of Northeast Thailand, the year-round data relating to draught activities from village household ploughing, raking and carting, show that the draught buffaloes are used on an average of between 51 to 67 days per year, ranging from 8 to 115 days (Chantalakhana, *et al.* 1991). Two or three draught buffaloes can take care of the farm work in a two to three hectare farm.

Table 3. Some characteristics of swamp buffaloes in small farms

Traits	Range of averages
A. Reproduction and mortality	
Age at puberty (year)	1.6-3.0
Age at first calving (year)	3.5-34
Oestrous cycle (days)	20-34
Gestation period (hour)	24-36
Gestation period (days)	308-322
Calving rate (%)	28-32
Calving interval (days)	370-670
Twinning (%)	0.001-0.015
Weaned calf crop (%)	23-22
Death loss (birth to weaning) (%)	10-30
B. Growth and carcass	
Weight at birth (kg)	26-32
Weight at weaning (8mo) (kg)	125-150
Weight of female (kg)	350-450
Weight of male (kg)	450-650
Dressing percent (bullocks)	43-51
Post weaning daily gain (kg)	0.34-0.75
C. Work	
Area of land plowed per hour (acres)	0.05-0.08
Days worked per year	20-146
Average years of work (in Thailand)	12

Bunyavejchewin and Chantalakhana, 1991; Chantalakhana, 1992

In Indonesia, it has been shown that the intensity of work by draught buffaloes varies widely from one farming system to another. The number of work days per year ranges from 10-30 days in

rainfed rice production to 200-300 days for cart haulage (Petheram, 1991). It has also been pointed out that in Indonesia draught animal power is most important in farming systems that are isolated, have no access to infrastructure facilities and have a high ratio of land to population density. It is also interesting to note that female buffaloes are more commonly used for work than males in most farming systems, which relates to their dual functions, i.e. work and production of the females.

Meat and milk

Buffalo meat is becoming more important in Asia since the demand for beef is increasing in most countries, where the beef supply from cattle cannot meet this rising demand for beef. Data presented in Table 3 show that the post-weaning growth rate of swamp buffaloes is 0.34 to 0.75 kg body weight per day on grass feeding with small amounts of feed supplement. The mature weight of buffaloes ranges between 450 to 650 kg, while the dressing percentage ranges from 43 to 51%. The quality of buffalo beef is comparable to cattle beef if the animals are of the same age and fed the same ration,

FAO statistics (FAO, 1994) indicate that buffalo meat production in China, Thailand, Indonesia and the Philippines in 1993 were 216, 58, 51 and 45 thousand metric tons. Due to rising slaughter rate of buffaloes, it has become evident that the buffalo populations in Malaysia, the Philippines and Thailand have decreased drastically during recent years.

Swamp buffaloes are not commonly raised for milk due to their relatively low milking ability. In general, 1 to 2 kg of milk can be obtained from a good buffalo cow, plus a certain amount of milk suckled by the calf. However, swamp buffaloes selected for milking in China can produce 441 kg of milk yield in 235 days of lactation, averaging 1.9 kg of milk per day.

Reproduction

The swamp buffaloes under small farm conditions where feeding and management levels are minimal, reach the age at first calving in 3.5 to almost 5 years (see Table 3). Under these conditions, the calving percentage generally ranges between 30 and 40 with a calving interval of 370 to 670 days. Due to various socio-economic as well as technical constraints, the reproductive performance of the swamp buffaloes under small farm conditions appears to be relatively inferior. However, whenever feeding and management are satisfactory, the reproductive traits of both buffalo and cattle under small farm conditions are quite comparable. Considering the harsh conditions and prevailing diseases and parasites in the tropics, it is highly satisfactory that these animals continue to produce in a sustainable fashion in rural areas.

Other products

Besides draught, meat and milk swamp buffaloes provide a by-product of significant importance during the year for use as fertilizer in crop production. In many countries, buffalo dung is used as fuel for cooking, by mixing with straw or chaff, moulded into patties and then sun-dried. Methane production from buffalo dung is practiced in some countries such as China.

Socio-economic value

Rural farmers in developing countries regard the swamp buffalo as a long-term family savings asset that can be converted when the need for a large sum of money arises, for instance in case of crop failure or cultural events. The buffalo can be used as an inheritance to be passed on to children. In many countries, buffaloes are used for game, recreation and as an agrotouristic attraction.

River Buffalo Production in South Asia

In traditional South Asian agriculture, the small farmer is basically a crop farmer. They maintain buffaloes mainly because they depend on these animals to carry out agricultural operations. Most of the farmers are subsistence farmers with very little land for cultivation. With heavy population pressure on land, the livestock number per farm is rather low. Most of the farmers keep around one or two buffaloes for crop cultivation or for milk production. Meat and manure are generally considered as by-products.

In India and Pakistan, one can recognize three systems of buffalo production, viz (1) extensive, (2) semi-intensive, and (3) intensive (Soni, 1991). In most of central, southern and eastern parts of India, the extensive system of buffalo raising is based in grazing on common village land, roadside grass and on stubble. Natural grass is supplemented with straw and other crop residues. Milk producing buffaloes are given a small quantity of cultivated fodder and also some oil cake are in a few instances. In Pakistan, the extensive system of buffalo production is practised in non-irrigated lands of Punjab and Sind provinces.

The semi-intensive system of buffalo raising is generally associated with intensive systems of crop production. The Province of Punjab, Haryana and Western Uttar Pradesh in India are the areas where farmers maintain 10 to 50 buffaloes under semi-intensive conditions. Buffaloes are raised mainly for milk production and are stall-fed. Cultivated fodder and natural grasses are cut and fed along with crop residues and a concentrate mixture. These animals provide most of the milk collected by the dairy plants in these states.

Metropolitan cities like Karachi in Pakistan and Bombay and Delhi in India have large herds of buffaloes raised under the intensive management system to meet the milk requirements of these cities. High producing buffaloes are purchased and brought from rural areas. These animals are kept under unhygienic conditions and fed straw and concentrates. A small quantity of green fodder is also given in the belief that this makes the straw based diet "tasty" to the animals.

Milk

The better known breeds of river or milk buffaloes reared in countries outside India are the Murrah and Nili-Ravi, where they have been introduced for milk production. In India most of the milk produced comes from buffaloes. Milk producing ability of river buffaloes varies according to breed, location, level of feeding and management and other factors. Table 4 shows the average milk yields in the first lactation of various breeds of the river buffalo.

In general, the average milk yield in the first lactation of the Murrah ranges from 1,500 to almost 1,900 kg and of the Nili-Ravi from 1,700 to slightly higher than 2,000 kg. Milk yields of the other breeds as shown in Table 4 are more or less close to the average of these two breeds. The lactation length of river buffaloes ranges from about 270 to 300 days, which is similar to that of the conventional breeds of dairy cattle. The average milk yield of the river buffaloes appears to be lower than that of dairy cattle under the same conditions, but the butterfat percentage is much higher (7 to 8 %). Therefore, buffalo milk is preferred by consumers in India in the preparation of traditional food products such as ghee or yogurt (Dahi). Buffalo milk composition is shown in Table 5. In general, both milk fat and solid-not-fat (SNF) in buffalo milk are higher than in cow's milk. The total solids percentage in buffalo milk ranges from 16.2 to 23.2 as compared to 13.4 in milk from Zebu cows.

Table 4. First lactation yield of river buffaloes

No. of animals	Mear $\pm$ SE (kg)	Source (cited by Bhat, 1992)
Murrah		
576	1709.5 $\pm$ 16.4	Kanaujia and Singh (1975)
3137	1753.0 $\pm$ 11.7	Sreedharan and Nagercendar (1978)
817	1867.4 $\pm$ 20.9	Kumar and Bhat (1978)
820	1601.6 $\pm$ 16.4	Kanaujia (1978)
380	1521.3 $\pm$ 22.5	Chhikara <i>et al.</i> (1978)
936	1962.0 $\pm$ 28.2	Bhularu and Dhillon (1978)
2137	1546.6168.1	Jain and Taneja (1982)
Nili-Ravi		
389	1706.5 $\pm$ 30.0	Reddy and Taneja (1984b)
1001 ^a	1702.0 $\pm$ 61.0	Cady <i>et al.</i> (1983)
1300 ^b	2065.0 $\pm$ 63.0	Cady <i>et al.</i> (1977)
Surti		
62	2203.0 $\pm$ 51.7 ^b	Singh and Singh (1977)
Bhadawari		
37	1165.0 $\pm$ 27.7	Singh and Singh (1977)
Nagpuri		
73	926.3 $\pm$ 17.1	Belorkar <i>et al.</i> (1977)
Marathwada		
23	845.7 $\pm$ 46.2	Singh and Singh (1977)
Egyptian		
285	1517.5 $\pm$ 32.5	Alim (1957)
230	1681.0 $\pm$ 31.8	Alim (1977)
170	1455.3 $\pm$ 42.7	Fahmy <i>et al.</i> (1975)

a Pooled over lactations

b The lactation length in Surti under reference was very high (426 days)

Table 5. Buffalo milk composition comparing to Zebu cow

Breed	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)	S.N.F. (%)	Total solids ^a (%)
Italian	81.9	7.8	4.2	^b	0.7	10.2	18.0
Egyptian	82.4	7.9	4.2	4.8	0.7	9.9	17.9
Chinese	76.8	12.6	6.0	3.8	0.8	10.6	23.2
Carabaos	78.6	10.4	5.9	4.3	0.8	11.1	18.9
Russian	81.0	8.5	4.8	4.9	0.8	10.4	18.9
Caucasian	82.7	7.6	4.0	5.0	0.7	9.7	17.3
Hungarian	83.8	7.3	3.6	4.5	0.7	10.0	18.2
Bulgarian	82.5	7.5	4.4	4.8	0.8	9.9	17.4
Murrah in Bulgaria	81.9	8.0	4.5	4.7	0.9	10.2	18.2
Murrah in India	82.7	7.4	3.6	5.5	0.8	9.8	17.2
Zebu cows	86.6	4.2	3.6	4.9	0.7	9.2	13.4

a Fat+S.N.F.
Rao and Nagarcenkar, 1997^bNot cited by authors

Buffalo milk can be processed into various dairy products similar to those from cattle milk. Cheese made from buffalo milk for instance, Mozzarella cheese in Italy, Domiati in Egypt or other cheese products from buffalo milk in India are well known and popular among consumers. Other dairy products such as butter, condensed milk, powdered milk, infant milk foods and various indigenous milk products can be made from buffalo milk (Ganguli, 1993).

Meat

The buffalo meat from the river breeds is used for consumption mainly outside India. The river buffaloes in European and Southwest Asian countries have often been called Mediterranean buffaloes and number approximately 5 million which are raised for the purpose of milk and/or meat production. The growth rates of river buffaloes in various countries as compared to cattle are shown in Table 6. It can be noted that the growth rates of river buffaloes vary from about 0.4 to 1.2 kg per animal per day, which depend mainly on the level of feeding and partly on genotypic differences. It is evident in Table 7 that the growth rate of river buffaloes are in general as high as that of cattle, while some are slightly superior. More details concerning growth and development of buffaloes can be found in the report by Moran (1992).

The mature body weight of the Murrah buffalo ranges from 350-700 kg in female and 450-800 kg in male. The adult weight of Caucasian river buffaloes is between 350-450 kg in females and 500-600 kg in males, while that of European buffaloes is between 250-600 kg in females and 400-800 kg in males. The Italian buffaloes average 650 kg in mature body weight of female. In general, the body size and weight of river buffaloes are comparable to those of Zebu cattle.

Table 6. Growth rates of river buffaloes and cattle (kg/day)

Country	Buffaloes	Cattle	Cattle genotype
Iraq	1.16(200)	0.89(122)	Genubi
USSR	1.12(265)	0.68(191)	Native
Bulgaria	0.90(271)	0.99(260)	Red Danish
	0.70(234)	0.91(300)	Red Danish
Egypt ^a	0.79(238)	0.87(257)	Native
USSR	0.75(253)	0.67(246)	Simmental
	0.73(225)	0.50(214)	Simmental
Iraq	0.73(150)	0.54(132)	Simmental
Bulgaria	0.72(151)	1.05(167)	Red Bulgarian
	0.74(158)	0.92(166)	Red Bulgarian
	0.64(159)	0.71(168)	Red Bulgarian
	0.72(150)	0.66(169)	Red Bulgarian
Egypt ^b	0.71(198)	0.64(157)	Native
	0.61(167)	0.61(200)	Native
	0.38(164)	0.41(165)	Native
Egypt	0.60	0.56	Native
	0.48	0.45	Native
India	0.53(150)	0.50(153)	Zebu
	0.49(152)	0.43(155)	Zebu
Sri Lanka ^c	0.51(132)	0.38(77)	Zebu
Trinidad	0.42(185)	0.14(140)	Zebu

^a Trial included Friesian 0.97 kg/day (294 kg)

^b Trial included Friesian 0.68(187); 0.58(182); 0.36(192) for the three trials respectively

^c Trial included Friesian 0.24 kg/day (114 kg)

Source Morgan (1992)

Figures in parenthesis are initial live weights (kg)

Table 7 shows some carcass and meat characteristics of river buffaloes. The dressing percentages appear to be about 54 to 55, which are slightly higher than those observed in the swamp buffaloes, but lower than in beef cattle. The percentage of lean meat in buffalo carcass is approximately 70 to 72% of the carcass weight. The loin-eye areas are about 60 to 64 cm², which is considerably smaller than in beef cattle. Carcass fat of the buffalo is white in colour while that of cattle is yellowish due to presence of carotene. Marbling in buffalo meat is very little as compared to cattle meat, hence, some claim that buffalo beef contains much less cholesterol than cattle beef.

Table 7. Growth rates, carcass composition and meat composition of three genotypes of river buffalo

Trait	Bulgarian	Merrah	Murrah x Bulgarian
Growth rate (kg/day)	1.02	0.95	1.03
Slaughter live weight (kg)	362	200.0	388
Cold carcass weight (kg)	194.6	54.7	209.7
Dressing per cent	53.7	54.7	54.1
Hide weight (% live weight)	13.9	12.5	14.1
Total lean meat in carcass (%)	71.9	70.1	69.4
10-11-12 rib			
Lean meat (%)	66.9	67.4	61.5
Separable fat (%)	15.4	15.8	18.6
Bone (%)	17.7	16.8	19.9
<i>Longissimus dorsi</i> muscle area (cm ²)	64.3	60.6	63.4

Oganjanovic, *et al* (1970)

The chemical compositions of buffalo and cattle carcasses are shown below (de Franciscis and Moran, 1991).

	Buffalo	Cattle
Cross chemical composition (% edible carcass)		
Water	71.0	72.0
Protein	20.8	21.3
Fat	7.1	3.1
Ash	0.9	0.8
Energy (kJ)	615	473

The amino acid, fatty acid, mineral and vitamin contents of the carcasses of buffalo and cattle appear to be quite comparable.

Reproduction

In general, it can be said that river buffaloes breed all year round, but variations in the breeding frequency in different months of the year could be observed in some locations due to the availability of good quality feeds, especially roughage, which can be affected by seasonal rainfall. The age at first oestrus of river buffaloes ranges from 30 to as high as 48 months. The number of AI services per conception ranges from 1.6 to 3.0. The age of cows at first calving ranges widely from around 37 to 55 months, depending mainly on the level of feeding and management. The gestation length in buffaloes is somewhat longer than in cattle, ranging from about 300 to 345 days. The calving intervals in Murrah, Nili-Ravi and Egyptian buffaloes vary between 480 to almost 510 days.

Breeding of river buffaloes using the artificial insemination technique with frozen semen is popular among dairy farmers. Research results in embryo transfer in buffaloes indicate that it is quite possible to employ this technique, but its economics and necessity has to be carefully assessed if it is to be used on a developmental scale.

Health

Buffalo diseases are generally the same as those of cattle, since the domestic buffaloes are closely related in phylogeny to cattle. There are, however, a few diseases of parasites that affect buffaloes more commonly or seriously than cattle, such as haemorrhagic septicaemia, black leg, round worms in calf and some skin parasites.

Haemorrhagic septicemia causes heavy economic losses in Asian countries due to high mortality among buffaloes. Some hundred thousand buffaloes in Asia are affected annually. Regular vaccination against haemorrhagic septicemia in buffaloes is provided as an extension service by governments of some countries. Black leg or black quarter is also a serious condition in buffaloes. It is an acute infectious disease characterized by inflammation of muscles, severe toxemia and high mortality. Other common diseases of buffaloes are foot-and-mouth disease, tuberculosis, mastitis, rinderpest and brucellosis.

It is evident that cattle and buffaloes share many common parasitic infections but buffaloes differ in many respects. There are some parasitic diseases, which are more common and pathogenic in buffaloes than in cattle. The main parasitic problems with river buffaloes are ascariasis, paracooperiosis, coccidiosis, fascioliasis and sarcoptic mange. Environmental factors, age of the animals and husbandry practices are some major factors that determine the extent of severity of different types of parasitic infections.

Buture of Buffalo Production in Developing Countries

Future trends in swamp buffalo production

In small farm production systems, buffaloes are used for draught and their manure for crop production. This practice will remain an important part of overall buffalo production in Asia for at least the next two or three decades, due to the fact that these systems of buffalo production is highly sustainable from biological, socio-economic and ecological standpoints. Lowland rainfed rice production systems will continue to exist, in spite of fluctuating market price, because much of the rice production in this ecosystem is produced traditionally mainly for home consumption. Sustainable rice yields depend on the use of animal manure as fertilizer for crops, as well as animal power for some farm work such as ploughing, puddling, raking, weeding, etc. Meanwhile transportation may shift from animal haulage to tractors, which can be used where a good village road system is in place.

While a substantial portion of small farm production continues to exist in many countries, a sizeable portion of these farms will continue to evolve and change their farming techniques and use of production inputs. In some extreme cases it has been seen, especially in irrigated areas, that farmers have given up buffalo raising for draught and turned to mechanization in order to adopt crop intensification techniques. Demand for buffalo beef by consumers in such areas has to be met by supplies from outside irrigated areas, consequently specialized buffalo raising systems will emerge when economic conditions are favourable.

Some small farms under rainfed conditions will also change in farming practices, for example with the availability of government credit for the purchase of small tractors. Some farmers will turn to mechanical power while some may have to sell a few buffaloes to meet the total cost of a small tractor. While using the small tractor for heavier or urgent farm works, buffaloes are also used for lighter works such as puddling and weeding. Buffaloes are raised utilizing rice straw and feed available around the farm as a source of farm income and regarded as assurance and security in case of crop failure. In other words, the buffalo is one of the necessary components contributing to the sustainability of small farm production systems. There will also be some farmers who depend solely on mechanization for farm power, but still will keep some buffaloes as a farm component in order to use the manure as fertilizer and sell buffalo for cash income.

Due to the growth in human population and the increase in per capita beef consumption in most countries, it is obvious that in the next three decades, the demand for beef will be significantly higher than at present. At present, the beef supply in some Southeast Asian countries is already inadequate to meet domestic demand. Some countries have to depend partly on imported cattle and buffaloes, either by legal trading or smuggling, while some have to enforce a slaughter ban in order to maintain cattle and buffalo populations at a desired level. Hence, it is foreseen that in the

near future beef cattle and buffalo farming or ranching will become a viable enterprise. Specialized buffalo raising on a small to medium scale (10 to 50 per farm) is likely to become more common, while larger ranch enterprises will depend on economic opportunities and government policy. Due to the lack of land and higher cost of production, large-scale buffalo ranching may not become a profitable enterprise, but again this will depend on many economic factors such as export markets.

Future trends in milk production from buffaloes

It is clearly evident that the total milk consumption in various countries in Asia will continue to rise due to an increase in human population as well as per capita milk consumption, due to increase in income and better education among people. The increase in milk consumption has been accelerated during the last decade in many Southeast Asian countries, where milk supply from dairy cows provide only around twenty per cent of the total milk demand. Besides, most rural people who form the majority of the population do not usually have access to commercial milk supplies. Hence, milk production from buffaloes can provide an additional source of milk supply to the commercial milk market, while crossbred or purebred river buffaloes on rural farms could provide milk for household consumption in rural areas. China and some Southeast Asian countries, such as the Philippines, Thailand and Malaysia are interested in and have commenced the implementation of programmes for crossbreeding of the swamp buffalo with some river buffalo breeds especially the Murrah and Nili-Ravi, in order to achieve good milking ability in the crossbreds, while at the same time, using them as a multi-purpose animals, *viz*, for meat, draught and manure.

Table 8. The milk yields of different buffalo breeds in China

Breed	Number tested	Average lactation (days)	Average lactation milk, yield (kg)	Average daily milk (kg)	Highest daily milk yield (kg)
Local (L)	10	235.9	441.4±212.4	1.94	5.5
Murrah (M)×L	12	276.9	1096.6±261.0	3.73	9.5
M×L(F ₁)	60	270.8	1153.7±397.5	4.3	11.0
M×(M×L)(F ₂)	12	291.7	1540.3±687.2	5.2	13.0
Triple-Cross [†]	NA	311.5	2100.7±645.0	6.75	12.5
Murrah	81	237.1	1573.2±524.2	6.61	7.0
Nili-Ravi	25	261.0	1873.5±690.4	7.21	9.9

[†] first lactation only

NA = number not available

Source: (Xiao, 1990)

China initiated a buffalo crossbreeding program to develop a dual-purpose animal *i.e.* for milk and meat in 1957 by introducing Murrah buffaloes to cross with the local swamp buffaloes. Later in 1974, Nili-Ravi buffaloes were introduced from Pakistan to be used in the three-way crossbreeding program (Xiao, 1990). Some results on milk production of the local swamp buffaloes (L), the Murrah, the Nili-Ravi and their various crosses are shown in Table 8.

A crossbreeding program involving the Philippines swamp buffaloes (carabao), the Murrah and the Nili-Ravi has also been carried out in the Philippines for more than ten years with the aim of producing a multi-purpose animal *i.e.* milk, meat and draught power. The results reported thus far relating to the milking ability of the crossbreds and their parental breeds are shown in Table 9. The details on growth, physiological characteristics and work performance of the different genotypes are also available (Momongan, 1992).

The difference in the number of chromosomes of the swamp buffalo (2n=48) and the river buffalo (2n=50) is the major concern of animal scientists. The F₁ crossbred (2n=49) between the swamp and the river buffalo appear to be fertile. The inter se mating of F₁'s produce crossbred buffaloes

of three cytogenetic types i.e. buffaloes with $2n=48$, $2n=49$ and $2n=50$, expectedly with the ratio of 1:2:1. The important question is whether or not the F_1 's will suffer reduced fertility in both male and female. The relatively few research evidences reported up till now have not shown that fertility of the crossbred buffaloes is significantly different from their parental breeds. However, well-planned and well-controlled research both in the field and in laboratory to examine the fertility of both male and female crossbred buffaloes need to be carried out before launching on any extensive development project in buffalo crossbreeding

Table 9. Average milk yield (kg) and lactation length (days) of the Philippines Carabao, Murrah, Phil-Murrah F_1 and Phil-Ravi F_1

Parameters	Philippine Carabao N=21	Murrah N=21	Phil- Murrah F_1 N=29	Phil- Ravi F_1 N=12
Milk yield	259.40	1804.40	705.60	623.10
Lactation length	200.81	348.48	259.45	233.67

Shrestha and Paker, 1992

Role of Buffalo in Small Farm Systems and Sustainable Agriculture

It is well recognized that most small-farmers (75 to 85%) depend on rain-fed agricultural production. They have practised farming or integrated farming for many centuries. Buffaloes have been incorporated as a vital component in these sustainable agricultural production systems. They continue to provide renewable resources in terms of draught power and manure, while meat or milk are secondary products in these systems. It is very evident in Thailand, where rice productivity during the last three or four decades has been sustained at a constant level, chemical fertilizer use has been minimal. Thai farmers in rain-fed areas have been using cattle and buffalo manure to maintain soil fertility. Manure is spread on to paddy fields early in the rainy season and ploughed down before rice planting. Each adult buffalo can produce 4 to 6 metric tons of wet manure per year. Besides being used as fertilizer, manure has also been used for other purposes such as burning fuel, construction material and others.

In most developing countries, draught animal power remains the important source of energy input per unit of cultivated land, in spite of the increasing use of petroleum-based power in some countries. From socio-economic aspects of existing farming systems in these countries, which are not expected to change **quickly** or drastically, the mixed use of all these sources of power in suitable proportions will offer the highest benefit to the farmers, especially those practising **rainfed** agriculture.

In the last two decades, farm mechanization has increased to various extents in many Asian countries. This raises questions concerning the future of draught animal power. But it is clear that the benefits of mechanization on crop yield will be realized only when other production inputs such as fertilizer, insecticide and irrigation become available and economical. It is therefore evident that under the prevailing rain-fed conditions and subsistence farming practices in developing countries, mechanization has not played a major role in sustainable crop production.

For Asia in general, in spite of the apparent increase in the use of farm machinery, especially in irrigated areas in most of the cultivated areas, the use of draught animal power will remain proportionately high. In many cases, draught animal power can be strengthened to complement the mechanized system.

Another important aspect of sustainable integrated farming systems practised by rural small-holders is the utilization of crop wastes and by-products, such as cereal straws, maize and sorghum stovers, pineapple waste, sweet potato vines and groundnut vines, for ruminant feeding. Buffaloes are known to digest such poor-quality roughage more efficiently than cattle, and in

developing countries small-farmers commonly use most of the crop wastes and by-products to feed animals, especially buffaloes. In some areas, where farmers do not raise buffaloes or other ruminants, they burn straw and stubble in order to dispose of them; this is wasteful, creates pollution and sometimes cause serious accidents.

It has been shown that the yield of wheat or rice straw is equivalent to the grain yield by weight. Maize stover is 70-75% and pineapple waste 60-80% of the grain yield. An enormous amount of fibrous by-products from cereals and other crops is available each year in many regions of the world. In developing countries, where most farmers are rural small-holders, these crop wastes and by-products are usually available in relatively small quantities at the farm; hence, they are not economically marketable. Some of these crop wastes such as stubble and stovers are left over in the field. Buffaloes also get rid of green weeds, provide manure to the fields through dung while grazing. These are among the many complicated and delicate components in sustainable agricultural production systems on small farms in rural areas.

Buffalo raising as part of small-farm agricultural systems has positive effects on the concept of social and economic sustainability, and consequently on rural development. Buffaloes are usually looked after either by women, old folk and children, who are not otherwise employed. Old folk in the family feel that they are useful and are needed when tending buffaloes. One of the major reasons why rural people choose to remain at home during the dry season, or not go to work in cities, is that they have to look after their buffaloes or other livestock.

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BUFFALO PRODUCTION SYSTEMS IN THE MEDITERRANEAN REGION AND LATIN AMERICA

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Abstract: Of the 166.7 million buffaloes in the world, 1.32 percent are located in Latin America and 2.01 percent in the Mediterranean region. The buffalo population in Europe is decreasing and is currently about 400,000. The population in Latin America is over 3 million, the largest number (about 3 million) being in Brazil. The best buffalo herds are located in Italy. This is a result of the intensive selection for milk production. In Bulgaria, the Bulgarian Murrah has been developed by upgrading the domestic Mediterranean buffalo with the Indian Murrah. It possesses high milk production potential, a rapid growth rate and the ability to adapt to a range of climatic conditions.

In Brazil, three large populations of the river type water buffaloes i.e. the Murrah, Jafarabadi and the Mediterranean are reared. In Trinidad, buffaloes of the Bufalypso breed are raised. This is a synthetic meat buffalo breed evolved by crossing the Mediterranean buffalo with the different river type buffalo breeds imported from India. The body conformation is characteristic of the meat type of animals with a very good growth rate and fattening ability. The system of management depends on the purpose for which they are reared and the condition prevalent in the different countries. In Greece, Albania, former Yugoslavia and Romania, from early spring to late autumn, buffaloes are raised on pasture while in the winter they are kept in primitive barns and fed roughage and low quality feed.

In Bulgaria, buffaloes are raised either in private farms under traditional management methods or in industrial complexes. In private farms in the winter they are kept in sheds and fed roughage and concentrate mixtures. In the summer, buffaloes are allowed to graze during the day and brought into the sheds for the night. In Italy, buffaloes production is well developed. Buffaloes are raised under commercial management conditions only for milk production. The milk is processed into a variety of dairy delicacies, mainly the world famous Italian "Mozzarella di Bufala".

Keywords: Production systems, Mediterranean, Latin America

Number and Distribution

According to official statistical data (FAO, 1997), the number of water buffaloes in the world is 166.7 million, of which 1.02% are located in Latin American countries and 2.01% are located in countries of the Mediterranean region (both in Europe and Egypt). However, the number of water buffaloes in these two regions is considered to be higher.

Mediterranean region

Europe

The number of water buffaloes on this continent is constantly decreasing and is currently considered to be about 400 thousand. In the past, water buffaloes were concentrated only in Southeast Europe (Albania, Bulgaria, Greece, Italy, Romania and former Yugoslavia). Presently, however, they are raised in other countries of the continent as well. The population is highest in Romania (about 150-180 thousand) and Italy (about 150 thousand), followed by Bulgaria (about 25 thousand; and former Yugoslavia. The number of water buffaloes in Albania and Greece is very small.

Egypt

There are about 3.2 million buffaloes raised in this country, 54% are located in Lower Egypt.

Latin America

Presently, over 3 million water buffaloes are raised in this region, located in almost all countries, and the population is increasing rapidly. The largest population is in Brazil (about 3.0 million), followed by Venezuela (about 100 thousand), Argentina (about 20 thousand) and in Colombia. The national buffalo populations in these countries are increasing rapidly at an annual rate of over 13-14%. Apart from Trinidad, that has a population of about 8 thousand buffaloes, the number of water buffaloes in the remaining countries is still limited. However the numbers are increasing each year.

History and Origin

Mediterranean region

Europe

There are several assumptions with regard to the introduction of buffaloes into the different countries of the continent. It is considered (Polikhronov, 1974; Alexiev, 1998) that buffaloes first came to Europe, more precisely to the Balkan Peninsula and Bulgaria. Their existence has been known for 12 centuries. They have been introduced from three directions: from the East via Bizantium, from the North with the invasion of the Huns and the Avars in Europe and from the South *via* Italy, where the introduction of buffalo most probably had been made from North Africa by the Saracenes.

There are several assumptions about the penetration of buffaloes into Italy. According to de Franciscis (1979), some authors assume that they have been known since ancient times, while others say that they have been introduced in the 6th century. It is also possible that buffaloes were introduced either from Egypt during the Arab invasion or with the crusades or in the 15th century. Cockrill (1974) reported that buffaloes have moved to Albania and Hungary during the Turkish invasion in the 16th century. According to Ivanov and Zahariev (1962) buffaloes have also been raised in some West European countries such as Germany in 874, France during the 12th century and in 1807 and England in 1252.

Regardless of when and how buffaloes were being introduced to Europe throughout the centuries, they were well accepted by the people in the Balkan Peninsula and Italy. They had not been raised in other European countries for ages. It was only recently that the importance of the buffalo was re-evaluated in these countries. Separate buffalo farms were established and some still exist in the United Kingdom, France, Germany, Spain and even Denmark.

Egypt

There is no evidence of the existence of the domestic buffalo during the time of the Pharaohs. It is widely accepted that buffaloes in Egypt were introduced from India and Iraq during the Arab invasion in the middle of the 7th century (Shalash *et al.*, 1988).

Latin America

Water buffalo introduction into this region started at the end of 19th century and at the beginning of the 20th century through import of buffaloes to Brazil, Trinidad and Argentina from Asia, Europe and Egypt. It was in 1890 that some political immigrants brought a group of swamp

Carabao buffaloes to Brazil by ship for the first time. Several years later, some Mediterranean buffaloes were imported from Italy and crossed with the Carabao buffaloes (Neto, 1985, Cabrera, 1988, 1991). A number of officially registered and illegal imports took place in the 20th century, resulting in the introduction of buffaloes of the Murrah, Jafarabadi and Mediterranean breeds as well as swamp buffaloes.

The water buffalo introduction into Trinidad started during the period 1903 to 1906, when buffaloes of the Indian breeds Nili, Ravi, Jafarabadi, Surti and Nagpuri were brought along by the settlers (Balaine, 1988). New imports took place in 1924, 1939 and some from India until 1949 (Cabrera, 1991), thus introducing the Murrah breed as well.

Mediterranean buffaloes from Brazil, Italy and Romania were imported to Argentina during the period 1900 to 1920, but interest in buffaloes was lost shortly afterwards (Zava, 1987; 1991). They were thereafter completely neglected. In the past 3 to 4 decades, water buffalo introductions took place in other countries as well. It has been most intensive in Venezuela, where buffaloes were imported from Trinidad from 1966 to 1972, from Italy in the 70's and 2113 buffaloes from Bulgaria from 1976 to 1992. Buffalo breeds raised in Trinidad and Brazil and lately, those in Venezuela are used as the genetic source for introductions into the remaining Latin American countries.

Buffalo Breeds

Mediterranean region

For many centuries, only Mediterranean buffaloes have been bred in Europe. The Mediterranean buffaloes raised in the different countries are similar in body conformation but belong to different types that have arisen as a result of the influence of different environmental conditions. Buffaloes in Albania, Greece and former Yugoslavia are of small size and are used as triple purpose animals for draft, meat and milk. Romanian buffaloes are bigger and are used both for milk and meat, as well as for draft in some areas. The best Mediterranean buffalo population is located in Italy. As a result of the intensive selection during the last four decades, the buffalo cows of this population are presently of big size and good body conformation of the dairy type. They are raised only for milk, while their meat production capacity is underutilized.

Bulgaria is the only country in Europe where the Bulgarian Murrah is bred. They have been evolved through up grading of the domestic Mediterranean buffalo with the Indian Murrah breed. Bulgarian Murrah is considerably different from the Mediterranean buffalo, by type and body conformation. It possesses high milk productivity, good growth capacity and excellent acclimatization ability in a range of climates. Mediterranean buffaloes (of Romanian and Italian origin) and the Bulgarian Murrah are raised on the newly established buffalo farms in the other European countries. Currently, the Italian Mediterranean buffalo and Bulgarian Murrah are used as a genetic resource for the development of buffalo breeding in a range of countries.

The buffaloes, raised in Egypt (Abdel Aziz, 1988) are of the same breed, with two genetically similar types, namely "Saidi" bred in South Egypt and "Beheri" in North Egypt. The "Beheri" type is bigger, gray in colour and higher in milk yield. The Egyptian buffalo is a multi-purpose animal, used mainly for milk, meat and additionally as a draught animal in some regions. Recently, some authors have tended to classify the Egyptian buffalo as the Mediterranean breed. However, this cannot be accepted, because this buffalo, though it is raised in a country bordering the Mediterranean region, is completely different in type and conformation, from the Mediterranean breed raised in the European countries.

Latin America

Buffalo populations in Latin American countries are quite variable by breed composition. They include both swamp buffaloes of different origin and buffaloes of the most famous breeds of the river type water buffalo and a large number of their crosses. In Trinidad, buffaloes of the Bufalypso breed are raised. This is a "synthetic" buffalo meat breed created in the period 1949 to 1960, by crossing river type water buffalo breeds, imported to Trinidad from the Indian subcontinent such as Surti, Nili, Ravi, Jafarabadi, Nagpuri, Bhadawari and Murrah. It has well expressed body forms, characteristic of the meat type animals, with a very good growth rate and fattening ability. However, the breed is not well established and stabilized by type, conformation and production as yet. Along with the good meat qualities, it is also characterized by higher milk yields compared to the swamp buffalo. Some individual animals with higher Murrah, Nili-Ravi or Jafarabadi blood levels can even be milked. The Bufalypso breed has become a genetic resource for introduction of the water buffalo into 14 countries and has widely spread to the whole of the American continent.

In Brazil, three large populations of the river type water buffalo, i.e. Murrah, Jafarabadi and the Mediterranean, have been formed by pure breeding and up-grading of the imported buffaloes and a fourth population of swamp buffaloes by purebred selection.

The Bulgarian Murrah is used as a major breed improver in Venezuela. In this country, a new dairy population of buffaloes of the Bulgarian Murrah type is being developed by expanded reproduction of buffaloes imported from Bulgaria and by intensive crossing with domestic buffaloes of the Mediterranean type and Bufalypso. Along with this, the breeding of the domestic population, including swamp type buffaloes and different crosses of unidentified breeds continues. In Argentina, Murrah, Jafarabadi and Mediterranean buffaloes and their crosses are maintained (Balaine, 1988; Zava, 1991). In the remaining countries; buffaloes of the swamp and river type and their crosses are raised.

Technology of Management

Mediterranean region

Europe

The systems of buffalo management depend on the purposes for which these animals are kept and on the prevailing conditions in the countries concerned. In Albania, Greece, former Yugoslavia and Romania, Mediterranean buffaloes are raised extensively by the traditional methods applied for ages. From early spring to late autumn they are raised on pastures close to rivers, marshes and lakes. In winter, they are kept in primitive barns and sheds, fed roughage and low quality feed (chaff, corn stalks, low quality hay, wastes from other animals feed, etc.) and even corn silage in some cases. Milking is done by hand, part of the milk being sucked by the buffalo calves. There were cooperative and state farms of different sizes in Romania. In the past, buffalo cows were raised under combined barn-and-pasture conditions for the production of milk and meat only. Machine milking and artificial insemination were applied in those farms. However, they were eliminated after 1990 and currently buffaloes are raised in the villages under the traditional methods.

In Bulgaria, buffaloes are raised in two different ways, either by the traditional method on private farms or under commercial conditions. On the private farms, buffaloes are kept under domestic rural conditions together with the calves. They are hand-milked twice a day but many farmers use machine milking. During the winter, the buffaloes are kept in sheds and are fed different kinds of roughage. In addition, they are given concentrate mixtures that are mixed with cut and scalded

straw or with cut beet. During the summer, the buffaloes graze all day and in the evening they come back to spend the night in the shed. In the past, there was a large number of social farms in Bulgaria. Buffaloes were raised in industrial complexes with a capacity to maintain 250 to 500 buffalo cows. These complexes used modern management technologies under full mechanization of all production processes.

Following the transition of the political system and the social and economic changes that took place after 1989, almost all social farms were closed down and the buffaloes were returned to their former owners. Now, there are only a few of these farms left with a reduced capacity. The establishment of new private buffalo farms, of smaller size has commenced. In the recent years, a large number of such farms were created with a capacity to maintain 20 to 150 buffaloes where machine milking is practised and buffaloes are raised only for milk and meat. The production of ecologically pure buffalo milk and meat delicacies has been started. The Association of Buffalo Breeders was created in Bulgaria, which stimulates the development of buffalo breeding in Bulgaria.

Buffalo breeding in Italy underwent a major development during the last five decades and the size of the buffalo population increased by about 12 times during this period. Presently, this formerly neglected animal is spreading throughout the country. Italy is now a country with a modern and strongly developed buffalo industry. Buffaloes are raised in commercial conditions only for milk production, the meat capacity being underestimated and poorly utilized. Buffalo raising is economically efficient because the buffalo breeders sell all the buffalo milk to the dairy plants for processing into different dairy delicacies, mainly the world famous Italian "Mozzarella di buffalo". Buffalo milk production is designed to meet to the requirements of the dairy industry, which imposes seasonal purchase prices, with highest price being offered during the summer season.

The buffaloes are raised mainly in free groups in semi-open type barns or in yards with a shed over the feeding corridors, but closed barns with yards are also used. Nutrition varies with the forage capacity of the farms. The big farms feed mono-rations prepared with silage, hay or straw and concentrates that are distributed mechanically by "UNIFEED". Buffalo cows are milked twice a day in milking parlours but many farms milk once a day (Matassino, *et al.*, 1993; AIA, 1997). Different systems have been adapted for buffalo calf management during the suckling period. On most of the large farms, they are raised in single cages in the open, under a shed or in barns. Usually, buffalo calves are fed warm milk prepared from evaporated cow milk powder and trained to eat hay, concentrates and silage. Lately, the feeding of acidified milk replacers have been increasingly practised. On some farms, buffalo calves are suckled by "nurse" buffalo cows or cows.

Egypt

Buffaloes in Egypt are raised predominantly by small farmers, who keep several animals on small plots of land. Of the total number of buffaloes in the country, 85.0% are raised by small holders possessing up to 3 buffaloes, 6.8% with 4-6 buffaloes, 3.0 % by medium holders with 7-10 buffaloes, 0.7% on the commercial farms with 10-30 buffaloes and only 1.0% on the intensive farms with over 100 buffaloes. The balance (3.0%) are located in the state farms. Three categories of buffalo production systems are applied in the country; the traditional, commercial and intensive systems. The traditional system is used by small holders, where animal housing and management is generally poor. The other production systems have been developed during the last two decades (Yousseff, *et al.*, 1997).

Temporary herds of lactation buffalo cows are raised close to the big cities for intensive buffalo milk production. There are large buffalo farms with dairies, where the entire quantity of milk

produced is processed and offered on the market as sour buffalo milk and other dairy products. There are also large specialized farms for intensive fattening of young buffaloes in the country for the production of buffalo meat. The feeding pattern of buffaloes in Egypt is subject to a great extent to the seasonality of forage and crop production. There are two systems of buffalo feeding, winter and summer feeding systems. Predominantly, berseem (green and hay) is fed with rice straw and minimum concentrates for producing buffalo cows (Yousseff, *et al.*, 1977).

Latin America

The importance of the buffalo as a source of animal protein for human nutrition was re-evaluated in Latin American countries in the recent decades. People have come to the understanding that this is an underutilized resource for the production of meat and milk, especially in the regions unsuitable for cattle. Presently, buffaloes are raised mainly on infertile and marshy areas in these countries.

In Brazil, buffaloes are raised mainly for the production of meat and lately for milk as well, under the prevailing extensive management system. At the same time, buffaloes are successfully used also as draught animals on some small farms located in marshy and highland areas, where mechanization is not possible to apply. There are different buffalo management and utilization systems in the country due to the various climatic and economic conditions in the separate regions. Pasture systems prevail, where buffaloes graze in herds, distributed by age. Milking of buffalo cows is done mainly by hand in the presence of the buffalo calves. In the southern parts of the country, buffalo calves suckle their dams up to about 6 to 7 months of age. Later, they are weaned and the male and female buffalo calves are raised separately. Male buffalo calves are castrated and fattened on pasture up to 480-500 kg body weight. Female buffalo calves are raised on separate pasture land and are fertilized by natural mating with a buffalo bull after 2 years of age (Neto, 1985).

Venezuela has excellent natural and climatic conditions for buffalo breeding and the country is called a "Buffalo Paradise". Buffaloes in this country are used for the production of meat and milk only. They belong mainly to large landholders, who raise them in large herds on pasture in marshy and infertile areas that are not suitable for cattle. The original purpose for the buffalo was for meat production on pasture, but this is now a developed industry. However, dairy buffalo breeding has been quickly expanding during the last two decades. The buffalo in Venezuela has already demonstrated its superiority compared to cattle in its ability to adapt to different management systems, that vary from systems that combine barn and pasture feeding in San Fernando to the extensive management systems in the other areas of the country. It has proved to be an important source of milk and meat for the country.

The hacienda "La Guanota" at San Fernando de Apure, a private sector farm has the largest number of buffaloes. On a territory of 20,000 hectares, 10,000 buffaloes of Bulgarian **Murrah** and its crosses are raised. "Closed" cycle of buffalo production is applied here. Young animals are grown wholly on pasture. The buffalo cows are kept in modern barns under a combined barn and pasture system of management and adequate nutrition. Milking is mechanized and takes place in a milking parlour. The entire quantity of buffalo milk produced is processed at a modern dairy into three delicatessen dairy products. Along with the **manufacture** of dairy products, young buffalo calves are fattened on pasture for meat production. This hacienda produces elite breeding material for the needs of the country and for **export** to Colombia.

Genetic Improvement

In the last two decades, there have been serious practical steps that have been taken for the genetic improvement of dairy characteristics of the different buffalo **breeds** and national buffalo

populations, in some countries. For this purpose and depending on the specific conditions in the respective country, two main breeding methods are used, namely purebred selection and crossing.

Mediterranean region

Pure breeding is practised in all countries of the region, but Bulgaria and Italy have developed national breeding programs for buffalo genetic improvement for milk. For the first time, the principles of population genetics developed in Bulgaria (Alexiev, 1979, 1992, 1998), used in the modern cattle selection programs were also applied to buffalo breeding in the Modern Program for Genetic Improvement of the Bulgarian Murrah. The same principles were also used for the development of the new Pakistani Program for River Buffalo Genetic Improvement (Asghar, *et al.*, 1993).

The Bulgarian National System, which is the basis for the genetic improvement of the Bulgarian Murrah, includes the following:

- Organizational structure of the buffalo population of two breeding units: active and passive.
- Milk and reproduction recording of buffalo cows of the active breeding unit. The information is computer processed
- Selection of hull dams.
- Progeny testing of the bulls under field conditions.
- Artificial insemination with deep-frozen semen.

Presently, the breeding policy is implemented by the newly created National Association of Buffalo Breeders in Bulgaria. In Italy, a number of selection activities have taken place in the last few decades, as a result of which milk productivity of the Italian Mediterranean buffalo increased considerably. The selection process is based on perfectly organized milk recording of buffalo cows, which is expanding every year. In 1996 (AIA, 1996), the milk recording system covered a total of 247 buffalo farms in 31 provinces. The total registered milk recording information, collected once a month, is processed at the National Computer Centre. The BME (Mature Buffalo Equivalent Production) index is calculated for each cow for milk yield, fat and protein. The milk recording results are efficiently used by the farmers in the practical selection of animals for replacement (females and bulls) in their own herds.

There has been a scheme for field progeny testing of buffalo bulls implemented in the country since 1986 for traits of milk productivity (Mozzarella cheese, milk, fat %, protein %, butter fat and milk protein yield). The introduction of artificial insemination with deep-frozen semen was begun but its acceptance encountered some difficulties. On many of the large farms, buffaloes are fertilized mainly by natural mating with bulls, and artificial insemination is avoided. According to Capasso *et al.* (1997), the current low use of artificial insemination has a negative influence on genetic improvement of the Italian buffalo population. For this reason, a Selection Experimental Scheme has been developed lately, based on a closed nucleus of farms and on the application of Ovum Pick Up (OPU) and in *vitro* Embryo Production (IVEP) techniques.

In Egypt, where about 95% of the buffaloes are located on the small rural farms, natural service is applied. There is limited application of some selection activities in the remaining part of the buffalo population. AI centers have been established to promote the implementation of artificial insemination with deep-frozen semen from purebred Egyptian bulls. Milk recording is limited and applied mainly on some state farms. Buffalo genetic research is carried out on the basis of this registered information. Abdel-Aziz (1993) points out that evaluation methods on "contemporary comparisons" are also used on a few farms where milk records are kept.

Latin America

In Brazil, pure breeding is used for the maintenance and improvement of the four basic purebred populations that have been created, Murrah, Jafarabadi, the Mediterranean and the swamp buffalo. The river type buffaloes in the country are subject to milk recording, based on which the farmers effect selection in their own herds, organize a number of shows, etc. Performance testing and progeny testing of the bulls is limited and done mainly for experimental purposes. Recently, some of the farmers have started the application of contemporary selection schemes at farm level. Such a scheme is applied at the "Panorama" hacienda for the Mediterranean buffalo. Along with purebred selection, crossing between different breeds is also carried out in the country. On some farms, mainly crossbreeding for up-grading of the Mediterranean buffalo with Murrah is practised.

In Trinidad, within-breeding has been applied during the last 2-3 decades for the improvement of meat production of Bufalypso breed. Performance testing for growth rate is applied as well. In Argentina, the Argentine Buffalo Breeders Association has an important role to play in the genetic improvement of imported buffaloes (Mediterranean, Murrah, Jafarabadi and crosses). It keeps an Official Register. Today, some 2,000 buffaloes appear in the Herd Book (Zava, 1997).

In Venezuela, where the national buffalo population is of diverse breed composition, pure breeding is applied only in the Bulgarian Murrah population of several thousand buffaloes, located on several haciendas. In the remaining part of the diverse domestic population, up-grading by crossing with Bulgarian Murrah is applied on a wide scale. Carried away by the increase of buffalo numbers in the country by expanded reproduction, buffalo breeders in Venezuela still do not take any serious selection measures for their genetic improvement.

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COMPARATIVE ADVANTAGE OF THE BUFFALO OVER DAIRY CATTLE IN THE ASIAN FARMING SYSTEMS

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Abstract: The majority of the world buffalo population is in the Asia Pacific region. Most parts of this region are characterized by high rainfall resulting in high humidity while the ambient temperature is also high. Dairy production in this region is aimed at breeding cattle with a high milk yield. As selection within the local indigenous cattle population is a slow process, decisions have been made to introduce high producing European breeds either for use directly in production or to upgrade indigenous breeds. Therefore, at present the populations of cattle used in milk production in this region are mainly high producing *Bos indicus*, *Bos taurus* or their crosses.

The prevailing high ambient temperature in this region interferes with heat dissipation *via* non-evaporative cooling while high humidity interferes with evaporative cooling. Other contributory factors that adversely affect cattle production in the tropical region are poor quality coarse roughage, limited grain feeding and parasites. The buffalo plays an important role in milk and meat production in this region. They are traditionally considered to be able to digest coarse roughage better than the cattle. Buffaloes have a comparatively heavier full and empty total gut than in zebu cattle. Several researchers have recorded a slower rate of passage of digesta through the buffalo gut compared to *Bos indicus* and *Bos taurus* cattle. Buffalo rumen also contains a higher density of total and cellulolytic microbial population compared to cattle. The greater volume of the gut of the buffalo may lead to a higher intake of roughage compared to cattle.

The buffalo is a study draft animal that is well adapted to paddy farming because its legs withstand continual wet conditions better than cattle. The animal is becoming popular as a meat animal as its meat is leaner than beef of neat cattle. Comparative heat tolerance studies have revealed that the buffalo can thrive in hot humid conditions better than *Bos taurus*. The dark and naked skin of the buffalo enables it to lose heat directly to water by wallowing. They also have a higher cutaneous evaporation rate although they are known to have a lesser number of sweat glands. A higher water turn-over recorded in the buffalo during wet seasons may be due to the higher intake of grass containing a higher percentage of water. All these physiological features make the buffalo a uniquely adapted animal to the hot humid tropics.

Keywords: Heat tolerance, humid tropics, buffalo, wallowing.

Introduction

The total numbers of cattle and buffaloes, in Asia Pacific region are 399.8 and 133.5 millions respectively, and the total cattle and buffalo populations in the world are 1277.7 and 138.4 millions respectively (FAO, 1988). This shows that almost all of the buffalo population in the world is restricted to Asia Pacific region. This region, which mainly experiences warm climatic conditions, is the belt around the earth lying between latitudes 30° North and 30° South, which includes the tropics. The climate in this region is not uniform. However, the tropical climate exhibits certain common characteristics. Most parts of this region are characterized by high rainfall resulting in high humidity. Except in the extremely dry areas, the daily and seasonal temperature variations are relatively small, being least at the equator. The average milk yield and growth rate of cattle in the lower elevations of this region are poor, being 10-25% of the standards at northern latitudes (McDowell, 1972).

A high level of animal production is desirable in the tropics, in order to supply the requirement of proteins with high biological value for the rapidly growing population. Selection within the tropical indigenous breeds is a slow process (Barker, 1975). This led to importation of high producing cattle from the developed countries, either for use directly in production or to upgrade

indigenous breeds. Therefore, the populations of cattle used in milk production in this region are mainly high producing *Bos indicus* cattle or crosses of *Bos indicus* and *Bos taurus* cattle. On the other hand, the buffalo plays an important role in milk production in this region, especially the high producing indian breeds such as Murrah, Surti and Nilli Ravi.

Climatic Conditions in Asia-Pacific Region

Although it is very difficult to define a typical tropical climate, the climate in Asia Pacific region is characterised by high ambient temperature and high relative humidity that interfere with heat dissipation by decreasing conduction, convection and radiation (Williamson and Payne, 1978). In these situations, cutaneous and respiratory evaporation plays a major role in heat dissipation in cattle (McLean, 1963). However, high humidity that prevails during the major part of the day hinders heat dissipation by evaporative cooling. Other contributory factors that could adversely affect cattle production in the tropical region are the poor quality coarse roughage, limited grain feeding and parasitic infestations.

This review, therefore, is aimed at comparing the physiology of cattle and buffaloes with special reference to heat tolerance and their ability to digest coarse roughage. Buffaloes are traditionally considered to be able to digest coarse roughage better than the cattle. The following scientific information supports this view.

Anatomical and Physiological Differences in the Gut of Buffalo and Cattle

Table 1. Comparative studies on intake and *in vivo* digestibility in buffaloes and cattle

	Digestibility (%)		
	Cattle	Swamp buffaloes	Reference
Guinea grass			
Dry matter	53.8	58.8	Johnson <i>et al</i> (1967)
Crude fibre	60.8	56.0	
Napier grass			
Dry matter	59.7	61.5	Escano <i>et al.</i> (1969)
Crude fibre	63.5	66.1	
Ensiled rice straw and water hyacinth with urea			
Dry matter	54.1	54.7	Wanapat <i>et al.</i> (1985)
Crude protein	29.9	32.8	
ADF	50.7	50.4	
Sweet corn stalk			
Dry matter	59.8	58.6	Cheva-Isarakul and Cheva-Isarakul (1984)
Crude protein	58.3	54.2	
ADF	51.8	49.9	

Moran and Wood (1982) have recorded that the comparative full and empty total gut weight is higher in buffaloes than in zebu cattle. The weight of the omasum and area of the internal laminae appeared to be smaller in Brahman cattle than in the buffalo and British cattle (McSweeney, 1988). Rana and Langhar (1980) measured rumen fluid dilution and outflow rates under similar dietary and management practices in buffalo and cattle. They concluded that on equal body weight basis buffaloes had a significantly higher rumen fluid volume and lower outflow rates than cattle. Homma (1994) also recorded a slower rate of rumen liquid turn-over in swamp buffaloes than in Holstein cattle. In a study to measure the rate of passage of stained straw particles through

the gut over a period of 24h, Jaffar and Malik (1996) have found that the percentage of particles excreted by Nilli Ravi buffalo, Sahiwal and Holstein x Sahiwal cattle were 17.8, 81.3 and 59.8 respectively. Bhattacharyya and Mullick (1985) have recorded that the interval between primary waves of the reticulo-rumen of buffalo was significantly longer than in zebu cattle. However, the interval between the secondary waves in two species showed no significant difference.

It can be concluded from the above evidence that the greater volume of gut in the buffalo may lead to a higher intake of roughage compared to cattle. Also the lower frequency of rumen movements in the buffalo causes a slower rate of passage of feed in the rumen, which may allow microbes to mix and digest the food particles over a longer period of time.

Characteristics of Rumen Microbial Populations in Buffalo and Cattle

Marked differences in microbial populations between buffaloes and cattle have been recorded in literature by several investigators. Several reports have shown that the density of the rumen microbial population in the buffalo was higher compared to cattle (Langar, 1968; Pant and Roy, 1970). Wattanacharanta *et al.* (1989) found that the total cellulolytic bacterial counts were $9.77 \times 10^9/\text{ml}$ and $7.50 \times 10^9/\text{ml}$ in swamp buffalo and cattle respectively. In another study, Chhabra *et al.* (1999) also found a higher total ruminal bacterial count in buffalo than in cattle. They also recorded a two-fold increase in the cellulolytic bacterial count in buffaloes than in cattle,

Table I represents a summary of some of the *in vivo* studies carried out to compare digestibility in buffaloes and cattle. A number of *in vivo* and *in vitro* studies have shown that both the swamp and water buffalo possess a greater ability to digest dry matter and cellulosic material compared to cattle (Ichhponai *et al.*, 1962; Krishna and Pradhan, 1984; Wanapat, 1984; Wanapat and Wachirapakorn, 1986). Devendra (1983 and 1987) reported that water buffaloes show a greater ability to utilize nitrogen than cattle. Buffaloes also have been shown to retain more nitrogen than zebu cattle (Devendra, 1985). Norton *et al.* (1979) reported that buffaloes had a greater ability to synthesize urea than cattle when fed poor quality roughage. The above studies confirm the superior ability of the buffalo compared to cattle in digesting the poor quality fibrous material that is very often available in the tropics.

Comparative Tolerance of Heat by Buffaloes and Cattle

As the difference between the ambient temperature and the skin temperature is minimal in domestic ruminants in the tropics during most parts of the day, dissipation of heat through insensible heat loss is ineffective, Therefore, animals will depend on evaporative heat loss through the skin to maintain heat balance. Several studies have shown that buffaloes have a lower ability to stand hot humid conditions compared to zebu cattle (Moran, 1973; Mullick, 1960). However, buffaloes have been reported to be less affected by hot humid conditions than *Bos taurus* cattle (Chikamune, 1986; Mostageer *et al.*, 1974). In a series of studies carried out to investigate comparative heat tolerance of *Bos indicus*, *Bos taurus* and Murrah buffalo, *Bos taurus* cattle consistently recorded the highest increase in rectal temperature, respiration rate and pulse rate when exposed to high air temperature and humidity (Tables 2 and 3). Murrah buffaloes were affected to a lesser extent while the effects on zebu cattle were minimal (Rajaratne *et al.*, 1983).

In our studies, we have found that the buffalo possesses a higher rate of cutaneous evaporation compared to *Bos indicus* cattle, and that *Bos taurus* cattle recorded the lowest cutaneous evaporation. Several reports show that the buffalo has a comparatively fewer density of sweat glands than cattle (Hafez *et al.*, 1955; Jenkinson and Nay, 1975; Saravanakumar and Thiagarajan, 1992). It is possible that cutaneous perspiration is higher in the buffalo, but this is not true sweating. Whatever the source may be, our studies have revealed that cutaneous evaporation is an important means of heat dissipation in buffaloes (Rajaratne *et al.*, 1983, Tilakaratne *et al.*, 1983).

Table 2. Mean values of rectal temperature, skin temperature, pulse rate, respiration rate and cutaneous evaporation rate of Murrah buffalo, *Bos indicus* and *Bos taurus* at 0700h during wet (W, ambient temperature 25.1 °C) , dry (D, ambient temperature 21.1 °C) and intermonsoon (IM, ambient temperature 26.2 °C) seasons.

	Rectal temperature (°C)			Skin temperature (°C)		
	IM	D	W	IM	D	W
Murrah Buffalo	38.4	37.8	38.5	33.7	31.1	30.5
<i>Bos indicus</i>	38.8	38.7	39.1	32.5	30.7	30.1
<i>Bos taurus</i>	39.0	39.1	38.9	33.8	30.1	31.0
	Respirations/min			Cutaneous Evaporation Grams of H ₂ O/m ² /h		
	IM	D	W	IM	D	W
Murrah Buffalo	21	20	21	346	277	479
<i>Bos indicus</i>	21	19	20	281	238	268
<i>Bos taurus</i>	33	46	31	160	185	169

Table 3. Mean values of rectal temperature, skin temperature, pulse rate, respiration rate and cutaneous evaporation rate of Murrah buffalo, *Bos indicus* and *Bos taurus* at 1200h during wet (W, ambient temperature 26.2 °C) , dry (D, ambient temperature 30.0 °C) and intermonsoon (IM, ambient temperature 26.2 °C) seasons.

	Rectal temperature (°C)			Skin temperature (°C)		
	IM	D	W	IM	D	W
Murrah Buffalo	40.1 ^x	39.7 ^x	38.8 ^y	35.9 ^x	37.5 ^x	32.9 ^x
<i>Bos indicus</i>	39.4 ^y	39.3 ^x	49.3 ^y	34.8 ^y	36.6 ^y	33.0 ^x
<i>Bos taurus</i>	42.0 ^z	40.7 ^y	40.0 ^z	36.6 ^z	38.3 ^z	34.4 ^y
	Respirations/min			Cutaneous Evaporation (grams of H ₂ O/m ² /h)		
	IM	D	W	IM	D	W
Buffalo	100 ^x	79 ^x	29 ^x	506 ^x	415 ^x	509 ^x
<i>Bos indicus</i>	57 ^y	30 ^y	25 ^x	464 ^x	437 ^y	391 ^y
<i>Bos taurus</i>	127 ^z	95 ^z	73 ^y	216 ^y	208 ^y	237 ^z

Means bearing dissimilar superscripts are significantly (p<0.05) different.

The highly pigmented skin of the buffalo, compared to that of the other two groups of cattle in our studies, would generally be expected to absorb more solar radiation resulting in a higher skin temperature. However, buffalo recorded lower skin temperatures compared to *Bos taurus*, although the differences were found to be statistically significant only in a few instances. Interference with heat loss caused by the relatively thicker hair coat of temperate cattle and the cooling effect on the buffalo skin brought about both through wallowing and through greater cutaneous evaporation may have been responsible for this result. The naked pigmented skin of buffaloes is a remarkable adaptation to the tropical environment. The pigments prevent entry of ultra violet radiation through the skin. The absence of hair on the skin provides a considerable advantage in losing heat by wallowing. This also allows the formulation of management practices to alleviate heat stress in buffaloes compared to the other hairy cousins of the family Bovidae. A large number of studies have been carried out to investigate methods of alleviating heat by either preventing exposure of animals to solar radiation or facilitating heat loss through the skin of buffaloes (Chikamunae and Shimizu, 1985; Perera and Perera, 1996; Rajaratne and Ranawana, 1996). However, the best method would be to allow them to wallow if facilities are available. In a grazing behaviour study carried out in the dry zone of Sri Lanka to compare the comparative adaptability of Lankan buffaloes with Surti and Murrah, it was found that on average, buffaloes were able to reduce the rectal temperature by 4°C after a 10-15 minute wallow, following grazing for an hour (Ranawana *et al.*, 1982).

Table 4 represents the results of a study carried out to compare water turn-over rates in Murrah buffalo, *Bos indicus* and *Bos taurus*. These studies on body water content and water turn-over rate has revealed superior ability of buffaloes to handle roughage containing a higher water content that is present in most of the wet tropics in major part of the year (Rajaratne, 1985; Ranawana *et al.*, 1982). This makes the buffalo a better adapted animal to the wet tropics compared to *Bos indicus* or *Bos taurus*. Although *Bos indicus* seems to cope with heat stress better than buffalo, their poor ability to consume large quantities of grass containing higher water content makes them less adapted to the conditions prevailing in wet tropics. We recorded loss of body weight by *Bos indicus* during wet seasons in the mid country of Sri Lanka.

Table 4. Daily turn-over of body water in *Bubalus bubalis*, *Bos indicus* and *Bos taurus* during three seasons (inter monsoon, dry and monsoon) of the year in Sri Lanka.

	Water turn-over (ml/kg ^{0.82} body weight/day)		
	<i>Bubalus bubalis</i>	<i>Bos indicus</i>	<i>Bos taurus</i>
Inter monsoon	^a 430 ^x	^b 333	^a 411
Dry	^{ab} 379 ^y	^a 319	^a 414
Monsoon	^a 463 ^x	^b 311	^a 411

Means bearing dissimilar superscripts are significantly ($p < 0.05$) different

a, b - species

x, y - seasons

The dark naked skin has given buffalo the ability to lose heat direct to water by wallowing. In this respect, the buffalo is only comparable to the elephant, rhinoceros and water hog. Its ability to consume large quantities of grass containing a high water content makes it adapted to climatic conditions with the high rainfall that prevails in most parts of the wet tropics. Several studies have shown that the threshold of body temperature for the initiation of respiratory cooling in the buffalo is far above the normal body temperature (Chikamune *et al.*, 1987; Rajaratne *et al.*, 1985; Rajaratne and Ranawana, 1996). This reveals the character of thermolability of the buffalo that is another unique physiological feature among all the domestic animals that are used in Asia Pacific region. On the other hand, some of our studies on dehydration of buffaloes have revealed that they can stand dehydration by reducing the faecal water output. All these evidences point to the buffalo as a better adapted animal than *Bos indicus* or *Bos taurus* to wet tropics.

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PLENARY SESSION - I

Review of Buffalo Production Systems

Discussion

Q. Oswin Perera - We saw a wide variation in the fat content of milk in the same breeds between countries, Is this in any way related to the yield of the animals?

A. S. K. Ranjhan - The variation will depend on the genetic make-up as well as the yield. In the Murrah, the fat content may vary from 7 to 10 percent. If the yield is low the fat content will be higher and if the yield is high the fat content will be lower. It also depends on the total lactation period and this is related to the genetic make-up of the animal.

A. J. A. de S. Siriwardene - I agree with Dr. Ranjhan. Both genetic and environmental factors have an influence. You will recall from the information presented that the Mediterranean crossbreds show a remarkable improvement both in body size and the ability to sustain a high level of milk production. This cannot be due only to the genetic effect, but due of a combination of the factors involved. I was particularly impressed with the results achieved in the 3-way crossbreeding programme experiment carried out in China, where they used the Murrah and Nili-Ravi on the local buffalo. The substantial improvement in production achieved I believe had more to do with the genetic influence.

Q. O. P. Danda - I have two questions. The first is, whether you got any data on the effect on weaning, because these animals do not respond well to weaning. The second is whether you have any information on the sexual behaviour in these animals. In our region they are known to produce silent heat and they are also seasonal breeders.

A. A. Alexiev - In Latin America weaning is done at 6 months of age and in Europe calves are allowed to suckle up to 3 months of age. We have problems both in Latin America and in Europe. About 70 percent of buffaloes do not show oestrus. This is the reason why AI has not progressed well. Farmers prefer natural mating in Latin America. AI is excellent in some herds where heat detection is made by parading bulls or with vasectomised bulls. In Europe, they use AI but there are difficulties. If heat detection can be organised well, there is no problem with the use of AI.

Q. S. S. E. Ranawana - They have been breeding buffaloes for several centuries. What was the purpose for which buffaloes were bred?

A. A. Alexiev - During the early period, they were for draught, milk and meat, but during the last 4 decades crossbreeding with the Murrah was connected with the development of the Bulgarian breed for milk and meat only. We do not use buffaloes for draught or for transport purposes.

Q. S. K. Ranjhan - I had the privilege to see the Bulgarian buffaloes at Shoumen. I have two questions. Murrah buffaloes that were imported were very small in number. My first question is did you encounter any breeding problems? The population of Mediterranean buffaloes that was reared by small farmers was 200,000. When you started to centralise your planning system, you applied a very high selection pressure on the 200,000 buffaloes and brought down the breeding population to 30,000, which were producing between 7 or 8 litres and above. So, precisely, the selection pressure that you applied on your Mediterranean buffaloes was as good as for milk production and meat production as the Murrah buffaloes that you imported from India. In the crosses that you got, the production was better because of the heterosis. My second question is, did you meet with any inbreeding problems in the Murrah herd which you imported from India

Plenary Session I

and when you did the cross-breeding between the Murrah and the Mediterranean, did you have heterosis in milk production or not.

A. A. Alexiev - We had no inbreeding problems. These were high **yielding** Mediterranean buffaloes. They were **crossea** with the Murrah animals that were imported on **two** occasions. We used the heterosis very well. We are very satisfied that our Bulgarian Murrah have given higher milk yields in other countries than in Bulgaria.

Q. A.N.F. Perera - You said that buffaloes are able to stay without water for 10 days. Is it water or is it dry matter?

A. A.A.J. Rajaratne - No. It is water. I carried out an experiment where buffaloes were fed dry hay. They went on for 10 days without a drop of water, except for the water in the hay.

Q. P. Skunmun - I would like to give my experience from experiments carried out in Thailand. We carried out a comparative study with beef and dairy cattle. Our conclusion was that buffaloes can use low quality roughage better under optimum feeding conditions. You mentioned only **about** the bacteria in the rumen. A group of Thai scientists found that the **rumen** of buffaloes not only had bacteria but also fungi at a higher concentration than beef or dairy cattle. When we ask farmers why they do not send buffaloes for grazing, they say it is very difficult to tend buffaloes compared to cattle. With cattle, they don't have to go back to the fields to give water, but with buffaloes they have to give water.

A. A.A.J. Rajaratne - Our situation is different. We generally use buffaloes on muddy fields, In **experiments** carried out in the dry zone at Polonnaruwa, buffaloes ploughing on dry land showed an increase in rectal temperature by 2-3 degrees and during grazing the rectal temperature can go up by 3 - 4 degrees. We also found that wallowing for 10 to 15 min after grazing for 1 hour can bring down to normal. This is the grazing behaviour of buffaloes under natural conditions. Buffaloes can tolerate an increase in rectal temperature to a certain extent without being effected too much, but this is not seen here. We do not use male buffaloes because they have too much testosterone.

Q. A. Borghese - It is not always true that the digestion capacity is higher in the buffalo compared to the bovine, because it depends on the **energy:fibre** ratio and depending on **which** breed of bovine you compare. In fact in my experience with Friesians, in the intensive system, the digestive capacity is higher in Friesians than in the buffalo.

A. A.A.J. Rajaratne - I quite agree with you. It depends on the quality of the feed. I am speaking here about low quality grasses.

Q. A. del Barrio - I would like to share with you my experience in the Philippines where we have the Carabao. We have some data on the digestive **system** of the crossbred **between** the Carabao and Murrah. We slaughtered more than 50 animals and compared the weight of the empty **rumen** of the Carabao and the crossbreds. It was shown that in the case of the native Carabao the empty weight of the **rumen**, in terms of body weight was higher when **compared** to the **crossbreds**. The crossbreds have a longer small intestine than the Carabao, which means **that** they will respond more to supplementation. This is one of the reasons why the crossbreds responds better to supplementation than the native Carabao.

A. S.S.E. Ranawana - The comparative advantage of buffaloes is not only that it can digest poor quality roughages, because of the larger **rumen**, but with slower movements and higher bacterial population. This advantage is not there when you feed good quality roughages. Secondly, I also want to say that because of the high rate of water turn-over, which means they can handle coarse material with a lot of water, which is the situation with a lot of forages around

Kandy. In that situation, neither the Zebu nor the Taurine cattle can handle poor quality material but the buffalo.

Q. A.D.N. Chandrasiri - My question is to Dr. Thu. You mentioned that in Colombia, calves are weaned at one year and that the calving interval was also one year. Can you clarify that statement?

A. N.V. Thu - One year is the maximum time for weaning. In Colombia, the male and female are maintained in the same herd and natural mating takes place. They want to deplete the herd and keep only the female calves. The calf follows the mother. They milk the cow and allow the calf to suckle the mother. The calf grows well and this brings in a big income.

Q. B.M.A.Oswin Perera - During the one-year period, the calf is allowed restricted suckling at milking time and sometimes the calves are let out with the mother. Weaning should mean the removal of the calf as soon as calving takes place. That is the question, how does the farmer do weaning?

Q. J.M. Seneviratne Banda - Do buffaloes need a dry period at the end of lactation? Some buffaloes do not experience a dry period. They continue to give milk until calving. This may be peculiar only to the buffalo.

A. E.R.K. Perera - As long as you continue to milk the animal, it will produce milk. Providing a dry period to the buffalo is the responsibility of the farmer. The next lactation will be better and the animal will have a rest period to replenish the depleted body reserves. As field Veterinarians, it is better to advise farmers to give a rest period of at least 45 days or a maximum of 60 days.

Q. M.R. Jainudeen - I have visited Darwin and seen buffaloes surviving with not water. So, how can you say that they have to dissipate their heat through water. They roll on the soil and dissipate their body heat.

A. A.A.R. Rajaratne - Buffaloes in Darwin are those imported from Indonesia. In my view, if they are not high producers, by changing their grazing behaviour, for example by grazing during the night and resting during the day, they can survive.

Q. M.R. Jainudeen - Then why is it that we call them water buffalo and not just buffalo

A. A.A.J. Rajaratne - If you see buffaloes in Hambantota or in any arid area where there is only salt water, they do very well. In fact they are able to produce high quality milk although the production levels are low.

Q. H. Makkar - Last week, we had a review meeting on one of our projects sponsored by IAEA where the counterparts compared buffaloes and cattle in terms of glomerular filtration rates. It was quite clear that buffaloes have got significantly lower glomerular filtration rates. It will also mean that this will lead to a higher recycling of nitrogen to the rumen leading to better utilization of low quality roughage.

A. M.C.N. Jayasuriya - In fact, there was evidence to show that if you feed too much nitrogen, it will poison the buffalo. Experiments where the rumen system is completely optimised, this ammonia could lead into the blood stream and poison them. This came out at the same meeting referred to by Dr. Makkar.

BUFFALO MILK PROCESSING AND PRODUCT DEVELOPMENT IN MEDITERRANEAN COUNTRIES

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Abstract: Europe and the Near East share only 3% of the world buffalo population, i.e. 4.9 million heads. Consistent numbers of buffaloes are at present registered in three European countries namely, Italy, Bulgaria, Romania, and 5 Near-Eastern countries namely, Egypt, Turkey, Azerbaijan, Iraq and Iran. In the last 15 years, a decrease in buffalo numbers occurred in most countries, except in Italy, Egypt and Iran. The decline is associated with three reasons. Holsteinisation of dairy cows, mechanisation and poor market demand for buffalo products.

The main purpose of breeding of buffaloes in Europe and the Near East is for milk. Everywhere buffalo milk is sold at a higher price than cow milk. Milk utilisation is very variable. In all countries, except Italy, buffalo milk is used also for liquid consumption. In most countries, several typical cheeses are produced, the most popular being the Italian Mozzarella. In Bulgaria, Iran and Egypt buffalo milk is used also for yoghurt production, but in Azerbaijan it is used only for 'ghee' production. Many farmers do their own processing of cheese and cream and they sell these products directly. Meat is considered a by-product everywhere and females are not slaughtered except at the end of their productive life.

The buffalo is no more used for draught in any of the considered countries, except in Egypt and in some farms in Romania. The lactation length averages 260 days. The average lactation milk yield is 1600 kg. The milk fat content over the entire lactation period is over 8% in many countries. Artificial insemination is performed only on 0.1% of buffaloes. The breeding goal is the genetic improvement of milk yield, but milk recording is at present done only on a small portion of the buffaloes.

Keywords: Buffalo milk, yoghurt, Mozzarella, milk processing, milk products

Buffalo Milk in Europe and the Near East

Europe and the Near East share only 3% of the world buffalo population, i.e. 4.9 million heads. The share of buffaloes in the global population of bovine animals is 0.4% in Europe and 0.6% in the Near East, whereas in Asia the percentage is 34. Despite the low numbers compared to cattle, buffaloes still play an important role in the economy of many countries as milk producers. In fact, the only breeding purpose of buffaloes in Europe and the Near East is milk production. Everywhere buffalo milk is sold at a higher price than cow milk. Milk utilisation is very variable, and the major difference from Asian countries is that milk is seldom used for liquid consumption, unless there is a surplus after production of butter, cream and cheese. Thus countries other than those in Asia exploit this peculiarity at the best, i.e. the higher fat and protein contents. It was demonstrated that in cases where no special dairy products are made from buffalo milk, buffaloes have been replaced with dairy cows, as cows are far more efficient in producing milk for liquid consumption. In fact, in the last 15 years, a decrease in buffalo numbers occurred in many countries of Europe and the Near East (Bulgaria, Romania, Turkey, Syria, Macedonia, Iraq). The decline is associated with three reasons: Holsteinization of dairy cows, mechanisation and poor market demand of buffalo products. Holsteinization that occurred in Europe increased dairy production in cows by two to four times that of buffaloes. Therefore buffaloes were substituted with Holstein where the environment allowed such substitution. Furthermore, mechanisation made the buffalo useless for field work and cart-pulling and cows milk came to be used in processing, specifically of many dairy products that did not require buffalo milk for processing, but could easily be produced also from cow milk. Buffalo numbers did not decrease, but sometimes even increased in areas where the market demand for buffalo dairy products is consistent, both in the form of fat products (cream and ghee) or special cheese.

Consistent numbers of buffaloes are at present registered only in three European countries, namely Italy, Bulgaria and Romania and also in five other countries, Egypt, Turkey, Azerbaijan, Iraq and Iran in the Near-East (Table 1). In Egypt, buffaloes number more than cattle. This makes this country very different from the remaining countries considered here. The increasing market demand for buffalo products resulted in an increase in buffalo numbers in Italy, Egypt and Iran. In Eastern Europe and Turkey, buffaloes were used in many cases for draught. With the advent of more and more tractors, buffalo number decreased. In the Near Eastern countries, where dairy cows give a lower average milk yield or similar yields in buffaloes, a decline in buffaloes were not registered. In Egypt, they are still useful animals for draught. In Egypt, Iran and Azerbaijan, there exists a consumer preference for buffalo dairy products compared to dairy products from cows. In Iran and Egypt, the increasing buffalo numbers seem to be associated with a global improvement of animal production, because the increase affected cattle populations to the same extent. However, in Bulgaria and Turkey, besides the consistent reduction in buffaloes, a drastic reduction in cattle was also evident.

Table 1. Buffalo and cattle populations in 1980 and in 1995 in Europe and the Near East

Country	Buffalo population		Cattle population	
	1980	1995	1980	1995
Italy	130,000 ²	175,000 ²	8,697,000 ¹	7,164,000 ¹
Romania	228,000 ¹	209,000 ²	6,351,000 ¹	3,481,000 ¹
Bulgaria	52,000 ¹	14,000 ¹	1,782,000 ¹	1,200,000 ²
Egypt	2,346,000 ¹	3,250,000 ¹	1,906,000 ¹	3,100,000 ¹
Turkey	1,031,000 ¹	305,000 ¹	15,467,000 ¹	11,901,000 ¹
Iran	242,000 ¹	519,000 ²	5,450,000 ¹	8,200,000 ¹
Iraq	172,000 ¹	105,000 ¹	1,630,000 ¹	1,250,000 ¹
Syria	2,700 ¹	2,700 ¹	778,000 ¹	778,000 ¹
Azerbaijan		305,000 ¹		1,633,000 ¹
Georgia		20,000 ¹		800,000 ¹
Europe	445,000 ¹	410,000 ¹	133,451,000 ¹	106,469,000 ¹
Asia	118,076,000 ¹	146,413,000 ¹	351,293,000 ¹	425,761,000 ¹

Sources: FAO Yearbook (1) or local statistics (2)

The FAO Inter-regional Research Network on Buffalo for Europe and the Near East (Buffalo Network)

The Italian Animal Production Research Institute is the co-ordination centre of the FAO Buffalo Research Network. This network is part of the FAO European System of Co-operative Research Network in Agriculture, which includes 13 networks, 6 of which have expanded to other regions than Europe. In 1992, FAO decided to grant funds to establish a Buffalo Research Network for the countries where buffalo research played a secondary role compared to cattle.

The Network has been active for several years and has succeeded in achieving the following goals (1) to create links between researchers of different countries in order to take advantage of each other's experience; (2) to promote the exchange of information and data on research concerning buffaloes; (3) to undertake collaborative research projects, facilitate documentation and organize joint meetings and (4) to promote the exchange of scientists and technicians. Italy, Bulgaria, Egypt, Romania, Albania, Poland, Greece, Syria, Iraq, Iran, Macedonia, Turkey, Azerbaijan and Hungary are members of the network. Through the network meetings and exchanges, much information was collected on buffalo milk and utilization in Europe and the Near East.

The International Committee for Animal Recording (ICAR)

The International Committee for Animal Recording (ICAR) is a non-governmental, non-profit organisation concerned with the progress of animal recording worldwide on a solid scientific and technical basis in collaboration with other institutions. Members of ICAR are the recording organisations of any country wishing to adopt and implement standardised methods for animal recording.

In 1996, the International Committee for Animal recording established a Working Group on Buffalo, composed of persons from research and recording organizations from India, Pakistan, Bulgaria, Egypt and Italy. Our Institute coordinates the activities of this Working Group which is working towards making an approved International Agreement for the recording of milk performances in the buffalo. From surveys conducted by the group (Moioli, 1996), much knowledge was made available on buffalo milk productivity in the world and on the organization of milk recording systems for buffalo. Official milk recording in buffalo is performed in India (over 12,000 recorded buffalo/year), Pakistan, Egypt, Italy, Bulgaria, Romania, England, Azerbaijan, Iran and Nepal. In Bangladesh, Sri Lanka, Iraq, Turkey, China, the Philippines, Thailand and Syria, milk recording is performed only in one or few research or State herds. Table 2 gives the average milk production data from various countries relating to the performance of officially milk recorded buffaloes. It is evident that the duration of lactation is variable, being longer (over 300 days) in the Asian countries, while it is below 270 days in the other countries. Productivity also is very variable, average differences reaching even 1000kg. It is obvious that milk production is highly affected by management, in particular by feeding conditions.

The basic rules for milk recording are in force in every country: all buffaloes in the herd are recorded; milk yield is measured once a month at morning and evening milkings; lactation yield is calculated by summing the average of two consecutive tests multiplied by the number of days between tests; lactation duration varies between 270 and 305 days. Regular sampling for individual analysis of butterfat is performed in India, Pakistan, Italy, England, Bulgaria, Romania, Iran and Nepal. Data on protein is recorded only in Italy, England and Bulgaria, indicating that most countries are more interested in fat products that are produced from buffalo milk rather than in cheese production.

Production, Quality and Processing of Buffalo Milk

Compared to cattle, buffalo milk is richer in butterfat and total solids. It has a lower cholesterol content and a higher tocopherol content. It is richer in calcium and phosphorous and less so in sodium and potassium. Peroxidase activity is 2-4 times higher, so that it can be preserved longer and beta-carotene is better transformed and thus milk looks whiter than cow milk. It can be consumed as liquid or processed into infinite types of products, either alone or mixed with milk of other livestock: fermented milks, butter, ghee, condensed and powder milk, cheeses. The following description refers to literature and surveys that we have conducted. If further details are required on the methods of processing buffalo dairy products, reference may be made to Renaud (1993; 1996).

Cheese and byproducts from cheese-processing plant

Many farms do their own processing of cheese and cream and they sell their products directly. Table 3 summarizes the cheeses of the Mediterranean area by grouping them according to their origin and the different stages of their technology and types of classification. The most common classification of cheese is made according to the type of coagulation: either enzymatic coagulation (due to rennet), or acid coagulation (by natural acidification or lactic bacteria). All cheeses undergo a mixed coagulation (both acid and enzymatic) though in some of them, the acid coagulation is prevailing, while in others the enzymatic is prevailing. Most of the cheeses produced in the Mediterranean area belong to the acid-enzymatic category, meaning that the acid

coagulation is prevailing, which can be understood because milk is left to acidify before adding rennet and because coagulation times are long. Looking at Table 3, it is evident that the acid coagulation is prevailing in all cheeses. A general consideration is now necessary, because technologies are the result of many factors and must fit in with the overall conditions of each environment. Each technology is affected by climate, by the availability of animal or vegetable rennet and by the characteristics of raw milk, which is also affected by climate and sanitary conditions of the herds. The Italian buffalo cheese called Mozzarella originated in southern Italy, where temperatures are high and buffalo rearing systems were mainly based on pasture. Therefore the technology of this cheese had to adapt to a kind of milk that, on reaching the dairy plant, is already acidified. The same most likely occurs with most Mediterranean cheeses.

In some cheeses, milk undergoes only a spontaneous acidification (Domati, Karish, Mish, Madhfoor, Alghab). In other cheeses, acidification is favoured by adding starters i.e. lactic bacteria cultures (Vladeasa, Beyaz peyneri) or natural whey cultures (Mozzarella). Starters are used also in cheeses where enzymatic coagulation prevails, in order to favour rennet activity in the processing stages that follow (White brine cheese, fresh cheese of Iraq, Braila). Table 3 includes also other important aspects regarding the treatment of milk before processing and peculiarities of the technology.

Pasteurisation, i.e. heat treatment of milk with the purpose of killing pathogenic microbes and reducing the microflora that can damage and cause losses in the final product, is performed only in few cheeses (White brine cheese, Domati, Braila, Vladeasa, Beyaz peyneri). Some cheeses are consumed fresh, i.e. after only few days of processing (Karish, Fresh cheese of Iraq, Mozzarella, Ricotta, Alghab), others are ripened and consumed even after several months. In this case, Mediterranean countries adopted the very wise practice of preserving cheese in brine, so that they can guarantee an excellent conservation without expensive investments, such as refrigerators. In fact, ripening and preserving of cheese without refrigerators in hot climates, could not only damage cheese, but also be hazardous to health of the consumers and may cause considerable loss of the products. In one cheese (Mish), it was observed that acid buttermilk, skimmed milk and whey are added to the brine.

In Table 3, cheeses are also grouped according to water content. Soft cheese has a water content higher than 45%; semi-hard cheese from 40 to 45% and hard cheese below 40%. In Table 3 a few technological peculiarities are made evident. In Domati and Akkawi cheese, salt is added to milk before processing. This practice is very common in Egypt and Syria, arising from the need to add bacteriostatics to milk, in order to limit the spontaneous development microflora during processing.

In two cheeses (Madhfoor in Iraq and Mozzarella in Italy) after the curd has been cut into pieces, the curd is left to acidify. Acidification is strictly dependent on the temperature, because it is caused by lactic bacteria, which grow at the best at high temperatures. After acidification, in the case of Mozzarella, the curd which has reached a pH of 4.8-4.9, is stretched. Then, it is moulded. The stretching phase is typical of Mozzarella: no other buffalo cheese is produced in this way. The stretching phase includes several actions: hot water is poured on the curd while the curd is kneaded and stretched, Then the whey is removed and further hot water is added several times, while the kneading and stretching continue. This technology phase is the crucial step in the making of Mozzarella and produces the typical stretched texture of the cheese. Stretching can be done either manually or mechanically. However, even in the bigger dairy plants, manual stretching is preferred because it improves both quality and yield of product. The stretching phase is important also because the hot water together with the curd acidity, help to improve sanitary conditions of the product. The following phase, the moulding into pieces of various weights (from 15 grams to 500 grams) and shapes (egg-shaped or braided) can also be performed either manually or mechanically. During the stretching phase, either salt can be added or the moulded pieces can be left in brine at 10-18% NaCl for a short time (from few minutes to few hours). Mozzarella is then preserved for a few days in acidified brine (2-3% NaCl).

Table 2. Milk Production Results (1998)

Country	Breed	Number of recorded lactations	Length of total lactation (days)	Milk production in total lactation (kg)		Length of standard lactation (days)	Milk production in total lactation (kg)	
				Average	Standard deviation		Average	Standard deviation
Azerbaijan	hzeni	8,737	276	1,656	491	270	1,452	445
Bulgaria	Bulgarian Murrah	516	270			305	1,805	
Egypt	Mediterranean	1,066	335	2,432	735		1,350	510
Iran	Azari	1,680	250	1,400	560	260	1,890	492
Iran	Khuzestani	1,260	230	1,910	502	200	1,150	530
Iran	Mazandarani	980	230	1,300	600	200	2,064	591
Italy	Italian	19,389	267	2,145		270	875	31
Nepal	Lime, Parkote and crossbred	234	351			305		
Nepal	Murrah x local	93	354			305	1,223	42
Nepal	Murrah Upgrades	61	380			305	1,560	51
Pakistan	Nili-Ravi	451	290	1,791	607	305	1,872	440
Romania	Mediterranean	304	291	1,356	352.6	182-265	1,076	301.3
United Kingdom	Mediterranean	68	207	2,337	1,214	270	1,855	1,012

Table 3. Dairy products

Type of cheese	Country of origin	Employed milk	Type of production	Pasteurization	Acidification of milk	Type of coagulation	Pressing	Technology peculiarity	Ripening	Water content
White brine cheese	Bulgaria	Buffalo	Industrial	Yes	Through starters	Enzymatic-acid	3-4 hours		In brine at 22-23% NaCl, for 35-40 days	Hard cheese
Domiat	Egypt	Buffalo or cow+buffalo	Industrial	Yes	Light acidification before coagulation	Acid-enzymatic	yes	Salt is added to milk (6-14%)	In brine until 9 months	Soft cheese
Karish	Egypt	Buffalo + skimmed cow milk or buttermilk after acidification of cream			Natural acidification during 1-3 days	Acid				
Mish cheese	Egypt		Home-made		Natural acidification during 1-3 days	Acid		Preserved in acid brine either with buttermilk, acid skimmed milk, or whey	In acid brine	Soft cheese
Rahss	Egypt	Buffalo or cow+buffalo	Industrial			Acid-enzymatic	yes		2-3 months at 12-18 °C	Hard cheese
Fresh cheese	Iraq	Skimmed buffalo milk			Through starters	Enzymatic	yes			Soft cheese

Table 3. (contd.)

Madhfoor or Dhafayer	Iraq			Light acidification before coagulation	Acid-enzymatic	Yes	Acidification of curd till pH 5.2	in brine at 10% NaCl, for 2 months	
Mozzarella	Italy	Buffalo or cow+buffalo	Home-made and industrial	Through addition of whey from the processing of the previous day. Whey undergoes a natural acidification at room temperature,	Acid-enzymatic		Acidification of curd till pH 4.94.9.2 and stretching in hot water	Preserved only few days in its whey + 2-3% NaCl, lightly acidified	Soft cheese
Ricotta	Italy	Whey from mozzarella processing	Home-made and industrial		Thermo-acid		protein precipitation of whey at 85-90 °C	4-6 °C for few days	Over 60% water content
Braila cheese	Romania	Buffalo	yes	Through starters	Enzymatic	Yes		In brine at 10-12% NaCl, for 1 month	Hard cheese
Vladeasa, Bucedis, Homoacod cheese	Romania	Buffalo or cow+buffalo	yes	Through starters	Acid-enzymatic		There are two types: high and low fat content	At 5-10 °C for 3 weeks	
Alghab/Hama cheese	Syria	Buffalo or cow+buffalo		Natural acidification during 3-4 hours	Acid-enzymatic	Yes	Coagulation lasts 3-4 hours		
Akkawi	Syria	Buffalo or cow+buffalo					Salt is added to milk (10-12%)	In brine	
Al Karish	Syria	From whey after Alghab processing			Thermo-acid		Protein precipitation of whey through boiling		Byproduct at higher water content
Beyaz peyneri	Turkey	Buffalo or buffalo+sheep/goat	Yes	Through starters	Acid-enzymatic		Coagulation lasts 1.5-2.5 hours	In brine at 12-14% NaCl, for 4-6 months	Half-hard cheese

Interesting byproducts from dairy plants are Ricotta (produced only in Italy) and similar products of Syria (Alkarish). They are made from the whey after the processing of cheese. It is surprising that in no other country are these byproducts exploited and the proteins are in whey (very rich in sulphurate amino-acids) are not utilised. It is possible to suppose either that the residual whey is too acid to let whey proteins to precipitate or that, being too fresh and with low acidity it is subject to change.

Fermented milks

Yoghurt is produced in Bulgaria, Romania and Albania, after pasteurization at 85-90 °C for 30 minutes, cooling at 40-42 °C, inoculation *with Lactobacillus bulgaricus* and *Streptococcus thermophilus*, fermentation for 3-4 hours and further cooling at 4 °C. In the mentioned countries, yoghurt is produced from either buffalo, cow or sheep milk,

In Egypt, Rayat is produced from natural acidification of raw milk during 72 hours, after the removal of cream, with no addition of bacteria. Zabadi is produced industrially, utilising the same processing technology as for yoghurt in the Balkans. Raha is the fermented milk of Iraq, produced either from whole or skimmed milk, after heating followed by cooling at 24-30 °C, for which it is possible to suppose that inoculation is done with mesofila bacteria. Laban or Khather are the fermented milks of Syria, produced from milk after heating and acidification (either spontaneous or through thermophilic bacteria) at the incubation temperature of 40 °C.

Creams

Creams also show variability of production. In Egypt, Queshta Mosakhana is the floating cream removed after boiling milk. Gaymar in Iraq is obtained both from spontaneous floating or from spinning, in this case it is then pasteurized. In Italy, cream from buffalo milk is obtained after spinning; then it is pasteurized. After thermo-acid coagulation (citric acid) of cream, another dairy product is obtained, called Mascarpone. Quishada (product of Syria) is obtained from raw or boiled milk; sometimes this cream is heated to make it more concentrated.

Butter and ghee

Industrial butter is produced by churning of cream, often after pasteurization. The home-made product is obtained simply by churning acidified milk. A peculiarity of buffalo butter is the colour, which is much whiter than cow butter, due to the lack of carotenoids. Ghee is obtained by boiling butter. It was very popular in Egypt and appreciated by the baking industry. In Azerbaijan, 'ghee' is the only product obtained from buffalo milk. It is evident that dairy products of the Mediterranean area need to be more deeply studied. The variability of their technologies is in fact an important part of global biodiversity.

The Development of Mozzarella

Among all Mediterranean cheeses, the Italian Mozzarella is the cheese which registers the highest level of production and forecasts indicate that production will increase in the future. The success of this cheese is correlated on the one hand to the consumer appreciation of this kind of cheese, including the three types, the whole buffalo milk Mozzarella, the mixed (buffalo-cow) and the whole cow milk Mozzarella and on the other hand to the evolution of buffalo farming. In fact, the increasing demand of buffalo milk together with the surplus production of cow milk in all Europe, have moved buffalo farmers to increase buffalo milk production through the improvement of management and feeding conditions, as well as milk recording and selection of best breeding animals. In fact, in Italy, 20% of the buffaloes are subject to official milk recording and genealogy registration. The average milk production of milk recorded buffaloes in a standard lactation is over 2,000 kg milk and a good number exceeds 3,000 kg. Although the buffalo sector has started to develop only recently, relations between buffalo farmers, milk processors and scientists are very intense. In our Institute, research is conducted on the effects of nutrition on milk quality (Tripaldi et al., 1997), and further experiments

together with private farmers are in course. Farmers themselves have promoted research. It was the farmers who requested that the 5th World Buffalo Congress be held in Italy in 1997 in the area of origin of Italian buffalo and actively participated in the Congress technical sessions on milk production, nutrition, meat, breeding, pathology, reproduction and management at which 195 papers were presented (Borghese *et al.*, 1997).

During the past few years, consumption and market demand for fresh cheese like Mozzarella has increased considerably. In order to distinguish and protect the Mozzarella made from buffalo milk, buffalo milk producers have created an association that drafted official regulations for producing Buffalo Mozzarella cheese and succeeded in obtaining formal approval of the Italian Government which enacted two laws in 1979 and 1993. Briefly, the regulations state that the following requirement must be followed in order to qualify for the name "Buffalo Mozzarella" to be used, Only buffalo milk must be used, milk must originate from the areas where buffaloes have been raised for centuries and the peculiar technology of processing that has been performed for centuries in these areas must be used.

Buffalo Mozzarella is different from the other types of Mozzarella in that it has a typical texture and a juicy consistency, apart from the special taste. Outside the original area of production (Naples and nearby provinces) Buffalo Mozzarella is considered a top quality product, to be consumed on special occasions. Thanks to the official stamp (green and red), printed on the wrapping paper, the buyer can immediately recognize Buffalo Mozzarella from other similar cheeses. Furthermore, the existence of approved rules as well as the special stamp permits detection and control of fraud.

The efforts of buffalo milk processing plants have promoted the expansion of the demand for this cheese on international markets. Mozzarella is a component of a typical Italian Food, the Pizza, which is known and appreciated all over the world and the success of Mozzarella was helped by the increase in Pizza consumption everywhere. The development of the buffalo sector in Italy has contributed to create new job opportunities both at the farm and at the dairy processing level. The development of the buffalo in an area in Italy, where the unemployment rate was at highest, because this area was less industrialized, has provided in particular, opportunities for employment of young people who in Italy were not consistently employed in agriculture,

Conclusions

Research in dairy technology has demonstrated that buffalo milk is suitable for processing of various dairy products, which has export value all over the world. It was demonstrated that sustainability of buffalo production both in Europe-Near East and in Asia can be increased through the implementation of appropriate key actions which exploit the results obtained by research Institutions. This is particularly so in the application of milk recording systems, progeny testing, reproduction biotechnologies and targeted breeding strategies that will contribute to increase milk production in the breeding stock. By intensifying international cooperation and exchange of expertise among research Institutions, Governments and development organizations, the buffalo will have many chances to survive and expand within the framework of a sustainable agriculture.

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BUFFALO MEAT PRODUCTION AND PROCESSING: RECENT DEVELOPMENTS

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Abstract: Water buffaloes have been bred primarily for milk and secondarily for meat and draught, whereas the swamp buffalo ($2n = 48$) has been bred primarily for draught, while meat and milk is of secondary importance. In India, farmers have shown a preference for raising milch buffaloes over milch cows. In spite of the high potential of the buffalo for meat, the meat industry has not utilized this resource sufficiently. About 6 percent of cattle and 11 percent of buffaloes are slaughtered each year. This is a very low extraction rate as compared to that in other Asian countries. India exported 175,000 tonnes of meat during the year 1993/94.

This paper discusses the major constraints that hamper Indian exports. These are (1) the insufficiency of the number of modernised slaughter houses (2) the limitation in the extents of disease-free zones (3) the high domestic demand and (4) the absence of the vertical integration between the production and processing sectors. In an attempt to increase the utilization and value addition of slaughter house by-products, the Government of India has placed greater emphasis on pollution control and the establishment of rendering plants and effluent treatment plants. Meat processing is undertaken by two sections, (1) the traditional sector, that caters to the local demands and (2) the modern plants that cater primarily to export markets. Buffalo meat is basically used in the preparation of traditional curries and kababs. However, buffalo meat is now used in the production of sausages, patties, nuggets, corned beef and ham.

Keywords: Meat, buffalo, production, processing.

Introduction

Water buffaloes ($2n = 50$) have been bred primarily for milk and secondarily for meat and draught in the Indian sub-continent (India, Pakistan, Nepal and Bangladesh), whereas swamp buffaloes ($2n = 48$), have been primarily developed for draught. Meat and milk are secondary products in South East Asia and China.

India has more than half of the world's buffalo population. The annual population growth in cattle and buffaloes has been 0.1 and 0.8 percent, respectively, during the last two decades. This is significantly higher in buffaloes as compared to cattle (Table 1).

Farmers in the northern belt have shown a preference for raising milch buffaloes over the milch cows. This is due to prevailing agro-climatic conditions, government policy towards ban on cow slaughter, mechanisation of agriculture, leading to a reduction in the proportion of the use of draught animal power in agriculture etc., have led to commercialisation of milk production through buffaloes. Already, in 17 Western Districts of Uttar Pradesh, most of Punjab, Haryana, lower Himachal Pradesh and Ganganagar area of Rajasthan, buffaloes are dominating the bovine population ranging from 75 to 90%. The trend in the other areas, where the buffalo population is growing fast is similar, such as in Gujarat, Maharashtra and Coastal Andhra Pradesh. With a virtual lack of backward integration with slaughter houses, about 5 million male calves are intentionally killed by farmers annually. These animals have the potential to be reared as meat animals to raise the standard of living of the farmers.

Table 1. Value of livestock output at current prices

Item	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	% share in 1995/96
1. Milk	27,508	33,885	338,448	43,407	49,919	53,162	54.3
2. Meat	7,208	8,493	1,485	12,489	13,917	15,272	18.5
2.1 Beef	686	841	1,139	1,477	1,613	1,770	2.1
3. By-products	696	869	1,034	1,236	1,388	1,523	1.8
3.1 Hides	270	378	417	531	614	674	0.8
3.2 Skins	306	350	426	509	583	610	0.8
3.3 Other by-products	120	141	191	196	191	209	0.2
4. Dung	4,307	4,355	5,340	6,413	6,980	7,703	9.2
4.1 Dung fuel	2,161	1,396	2,363	2,880	3,172	3,455	4.2
4.2 Dung manure	2,146	2,501	2,977	3,533	3,808	4,148	5.0
5. Value of livestock products	42,340	50,941	58,361	57,267	76,512	82,734	100.0
6. Value of agric. output	128,657	149,881	164,562	188,252	217,336	232,290	
7. Total value	170,698	200,822	222,923	255,518	294,412	314,994	
8. Total GDP	477,800	552,800	630,200	723,100	858,300	958,800	
9. % share of livestock in GDP	6.45	6.78	6.35	6.94	6.66	NA	
10. % share of agriculture in GDP	28.30	28.82	23.23	28.35	27.67	25.61	

Source: Basic animal husbandry statistics (1997), Department of Animal Husbandry and Dairying, Ministry of Agriculture, India.

Table 2. Trends in livestock population and meat production over two decades (1975-1995)

Livestock species	Population (in millions)		Slaughter rate (%)		Carcass weight (Kg)		Meat production ('000 MT)		% share of total production	
	1975	1995	1975	1995	1975	1995	1975	1995	1975	1995
Cattle	180.1	194.6 (6.7)	4.9	6.4 (4.5)	82	103 (28.0)	724	1292 (761.3)	35.3	31.2
Buffaloes	50.5	79.5 (23.3)	9.3	11.0 (-)	139	138 (-)	780	1204 (692.1)	38.1	29.1
Sheep	40.1	45.0 (9.0)	31.9	31.3 (12.6)	9	12 (33.3)	117	173 (28.1)	5.7	4.2
Goat	69.7	119.4 (46.5)	42.5	39.7 (-6.5)	9	10 (11.1)	269	474 (50.5)	13.2	11.4
Dogs	7.0	11.9 (35.2)	25.7	35.3 (17.7)	31	35 (9.4)	56	420 (394.1)	2.8	10.1
Poultry	141.0	610.0 (378.9)					101	578 (259.0)	4.9	14.0
Total	498.4	1060.4 (96.6)					2047	4141 (315.9)	100.0	100.0

Figures in brackets are percentage increases over the previous two decades.

Meat and Meat Products Industry

In spite of the big potential, because of large livestock population and competitive edge in the international market due to cheap labour, the meat industry in India has not assumed the status in keeping with its potential. Meat production has increased five folds from 764 thousand tonnes in 1970-71 to 4.3 million tonnes, valued at more than Rs.155,000 million (US\$3800 million). The compound average annual growth rate during the last two decades works out to 7.6% as against 21.7% during the last 5 years (Table 1).

Demand for Meat

The precise calculation of the meat demand in India is difficult and prone to variation. However, for purposes of calculating the minimum requirement of meat, it is assumed that a third of animal protein requirement (15g) should be provided by meat sources. This accounts for 30g of carcass meat or 5g of meat protein. Assuming that 70% of the 1000 million human population is non-vegetarian, the demand for meat is placed at 7 million tonnes. The present level of meat production is 4.2 million tonnes, which need to be increased by 70%. This is possible even with current animal population, either by increasing the productivity of meat animals or by increasing the extraction rates through effective culling of unproductive and excess buffaloes, sheep and goats. At present, buffalo meat is consumed only by 10-15% of the non-vegetarian population, whereas mutton and chicken meat is consumed by all non-vegetarians. Therefore, there is a large surplus of buffalo meat available for export than mutton, which is consumed locally by almost all section: of the society. Therefore, prices of the latter are rapidly increasing as compared to buffalo meat.

Extraction Rates for Animals for Meat Production

The trends in livestock population, slaughter rate (numbers slaughtered as percentage of the population), carcass weight and meat production in India over two decades (1975 to 1995) are shown in Table 2. It is observed that about 6% cattle and 11% of buffaloes are slaughtered each year. This is a very low extraction rate when compared with the other Asian countries. Actually, the extraction rate could go up to 30% for each of the two species, without affecting milk production and draught ability in the country. The share of bovine meat production, of the total meat produced in India, is about 60%, as against that of the small ruminants (15%) and pigs and poultry (10%) and (14%) respectively (Table 2). With the increasing mechanisation in agriculture, more large animals will become surplus, especially the male buffalo calves, that do not have a market for draught and are deliberately killed by the farmers, thus resulting in huge wastage and consequential loss to farmers. About 10 million sheep and 50 million goats are slaughtered annually accounting for 31% and 40% of the extraction rate, respectively. This too could be increased to 45% (Table 3).

Components of Meat Industry

There are 10 distinct components of meat and meat by-product related industries:

- Trade in live animals: buffaloes, sheep, goats, pigs, bullocks.
- Slaughter of animals by individual butchers for retail domestic markets.
- Slaughter in the mechanised abattoirs (EOU)* for export.
- Transportation of fresh frozen meat in refrigerated containers from the point of production to the port.
- Marketing of raw hides and skins.
- Marketing of bones for further processing into gelatine, ossein and DCP**.
- Production of casings from the intestines.
- Cottage industry utilising hooves and horns.
- Marketing of blood for production of pharmaceuticals.
- Rendering plants for production of meat-cum-bone meal and tallow.

* EOU - Export Oriented Unit

** DCP B Dicalcium Phosphate

Table 3. Extraction rates of different categories of animals in India and some Asian countries

Animals	India	Pakistan	China	Egypt	Indonesia	Asia
Buffalo						
Total No.	78.5	18.2	21.9	3.0	3.4	112.2
Slaughter No.	8.5	3.4	2.0	1.3	0.3	16.7
Extraction rate	10.8	18.7	9.1	43.3	10.0	11.7
Cattle						
Total No.	192.6	17.7	82.7	3.0	11.0	397.7
Slaughter No.	11.8	1.7	11.6	1.2	1.3	43.4
Extraction Rate	6.1	9.6	14.0	40.0	11.8	10.9
Sheep						
Total No.	44.4	26.9	111.1	4.3	5.99	344
Slaughter No.	13.8	11.3	58.0	2.8	4.5	155
Extraction rate	31.3	42.0	52.2	65.1	75.0	45
Goats						
Total No.	117.0	38.5	95.03	4.8	11.4	395.4
Slaughter No.	45.6	20.8	55.5	1.9	5.5	102.3
Extraction Rate	39.0	94.0	59.4	39.6	48.2	47.0

Most of the registered slaughter houses are very old, unhygienic and lack essential services such as, water, drainage, waste disposal and effluent treatment, except only in a few recently built mechanised abattoir-cum-meat processing plants, which primarily cater to export demands from sophisticated foreign markets.

Export of Meat and Meat Products

The major source of meat and meat products for export is from buffalo, sheep and goats. The largest share of exports has been from buffalo meat, which amounted to 157,000 tonnes, valued at Rs.9100 million in **1997-98** (Table 4). Buffalo meat exports exhibited a tremendous growth. Exports almost trebled between **1988** and **1998**, rising from 51,205 tonnes to 175,000 tonnes.

Table 4. Export of buffalo meat from India (MT)

Countries	1993	1994	1995	1996-97
Malaysia	38,438	40,000	45,000	57,000
UAE	22,962	25,000	30,000	35,100
Jordan	10,421	15,000	15,000	2,200
Yemen	5,869	6,000	6,500	300
Oman	5,538	6,000	6,000	6,700
Kuwait	4,911	5,000	5,000	3,800
Mauritius	3,843	4,000	4,000	3,800
Singapore	3,265	3,000	3,000	200
Bahrain	2,128	2,000	2,000	2,000
Philippines	1,254	1,500	1,500	25,300
Iran	1,077	1,000	1,000	7,700
Qatar	432	500	500	550
Brunei	229	0	0	225
Others	1,527	1,500	500	500
Total	132,000	110,000	120,000	143,575

Note The 1993-94 exports included 15,450 MT of fresh/chilled boneless meat and 66,700MT of frozen boneless meat. The balance was mostly fresh, chilled and frozen carcasses and half carcasses. In 1997-98, it was 157,000MT and in 1998-99, it was 175,000MT.

Still, the total buffalo meat exports account for only 10% of the domestic output. Some private state-of-the art abattoir-cum-meat processing plants have established a niche in the international markets, like in the Philippines, Malaysia, Iran, Egypt, the Gulf, Middle East and CIS countries.

India's export of sheep and goat meat has been small because of the greater demand in the domestic market. However, India exported 14,000 tonnes during 1995-96. The world trade in poultry meat is estimated to be about 2,500 MT valued at US\$4,500 million. Export of poultry meat from India was started recently. Exports during 1991-92 amounted to about 250 MT, valued at Rs.11.5 million, which increased to 603.48 MT in 1996-97.

India's exports of animal casings and processed meat are small. However, the export of bones, bone products, and horn and hoof meal is substantial. In 1992-93, the value of exports amounted to Rs. 834.1 million, the main products being ossein, bone grit, crushed bones and gelatine.

Major Constraints to Meat Export

Some of the factors, which hamper Indian exports, are given below. These bottlenecks are being removed and the meat industry is progressing rapidly.

Insufficient number of modern slaughter houses

There are just about 5 modern integrated slaughter houses, which have world class sanitary and phytosanitary conditions. These are the Hind Agro Industries in Aligarh, Allanson in Aurangabad, Al- Kabeer in Hyderabad, Punjab Meats in Chandigarh and Deonar (Public Sector) in Mumbai. Besides these, there are 32 modern meat processing plants, which receive dressed carcasses from modern municipal slaughter houses and process the meat for export to Middle East. However, many countries like the Philippines, Malaysia, Iran, Egypt and Jordan insist on meat processed in integrated slaughter houses. With the increase in demand for meat from integrated slaughter houses in the international market, there is potential requirement to establish/upgrade 20 more mechanised abattoirs, to utilise about 10 million surplus buffaloes available annually. Each abattoir should have facilities to slaughter 0.5 million animals annually.

There are 3,643 slaughter houses registered with municipal authorities and more than 10,000 unregistered slaughtering areas, which lack adequate facilities and basic amenities required for hygienic production of meat. The handling capacities of these units vary from 100-500 for large animals and 25-800 for small ruminants per day. These abattoirs fall short of the standards and norms required for quality meat production. The Government has launched a scheme to provide assistance to upgrade these slaughter houses with a 80% subsidy which is now being utilised by many meat companies.

Insufficient disease-free zones

There are some trade-related diseases, which restrict export of meat to many countries. As per the O.I.E. List 'A', the diseases are. Rinderpest, Foot and Mouth, Contagious Bovine Pleuropneumonia, PPR, Blue Tongue, Vesicular Stomatitis etc. The existence of foot and mouth disease (FMD) alone restricts the export of meat to many countries. FMD is still prevalent in a few pockets in the country, although the Export Oriented Unit (EOU) has established FMD free zones through vaccination. In the 9th Five Year Plan, the Government hopes to completely control this disease.

High domestic demand

There is a great demand for poultry and mutton from the large human population in the country, whereas buffalo meat is consumed only by 10 % of the population. Therefore, there is a big potential for buffalo meat exports, which could be increased to 200,000 tonnes and above from year 2000 AD onwards.

Lack of vertical integration between production and processing

Unlike in the dairy industry, there is virtually no vertical integration between production and slaughtering. The large state-of-the-art abattoirs have a high intake of 500- 2000 animals per day. These abattoirs may slaughter between 0.5 to 0.8 million animals annually. Therefore there is a need for rearing of male buffalo calves, which are otherwise intentionally killed by the farmers due to lack of marketing outlets. The Hind Agro Industries Limited is one company which has initiated such a project. Under this project, animals of farmers are regularly vaccinated and bought by Hind Agro Industries Limited (HAIL) under a buy back scheme, thereby raising the standards of living of the farmers at one end and producing quality meat at another.

Quality Meat Production in Integrated Slaughter Houses

A flow diagram for production of quality meat in integrated slaughter houses is given in Figure 1. This shows the protocol of slaughtering and utilisation of slaughter house by-products, in a rendering and effluent treatment plant. Because of the great emphasis given by the Government to pollution control, slaughter houses in bigger towns are obliged to establish the rendering plants as well as effluent treatment plants to process value added by-products.

Changing the Global Scenario and Export Potential

India's international trade in livestock and livestock products is mainly in live animals (17%), meat and meat products (82%) and dairy products and eggs (1%). At the global level, India's exports and imports account for only 0.17% each. Meat and meat products have dominated exports. The trend analysis of animal growth in these categories, namely, live animals, meat, meat products and dairy products and eggs, have been estimated at about 25%, 23% and 9% respectively.

The meat sector is growing very fast and has a big potential for export since the buffalo meat produced in India, is marketed at US\$1000 to 1400 per tonne, as against US\$ 1500-3000 per tonne of Australian meat. Although international prices of meat have declined recently, they are likely to increase due to reduction in the subsidy given by the developed countries for livestock raising. Therefore, India is likely to become a major player, provided meat is hygienically produced and the disease free zones are recognised by O.I.E. immediately.

Meat processing

Meat processing in India can be divided into two sectors, namely, the traditional sector to meet the local requirement and the modern commercial sector for export.

The meat for local consumption is mostly consumed within 8 to 10 hours of slaughter. Meat handling and transport from abattoirs to markets in hot environmental conditions are generally done rapidly during the cooler hours of the day. Transportation is generally done in covered vans from the abattoirs to the retail shops, where it is sold in the wet market.

The meat meant for export has to pass through ante-mortem and post-mortem inspection, as with meat meant for local market and then chilled for 24 hours to bring down the pH below 6. Thereafter, it is deboned and deglanded. The meat is then packed in different cuts and frozen at -40°C for 12 hours to bring down the deep bone temperature to -18° C. The frozen meat is kept in cold storage for export.

Buffalo meat products

In India, buffalo meat is basically used in households for preparation of curries and Kababs. It is also mixed with vegetables like potatoes, cabbages, turnips, sugar beat to make delicious dishes,

to name a few, besides the irresistible **Biryani**, which is a mix of meat and rice. Buffalo steak is also a delicious product. Both **seekh** and shami Kababs are delicacies prepared from buffalo meat, which is liked by all classes of people in India. Buffalo meat has great water holding and binding properties, and is therefore used for industrial purposes in the production of sausages, patties, nuggets, corn beef, ham etc. A large part of the meat in the Philippines, Thailand, Iran etc., is used for the production of ham and sausages.

Meat quality

Buffalo meat has been shown to be of superior quality as compared to cattle beef. The American Water Buffalo Association (AWBA) has reported that meat of the water buffalo has 41% less cholesterol, 92% less fat and 56% less calories than cattle beef.

With increased mechanisation, the buffalo will be a major producer of milk and meat in the twenty first century in India. With efficient rearing, they can gradually replace cattle in buffalo dominated farming systems in the whole of North India.

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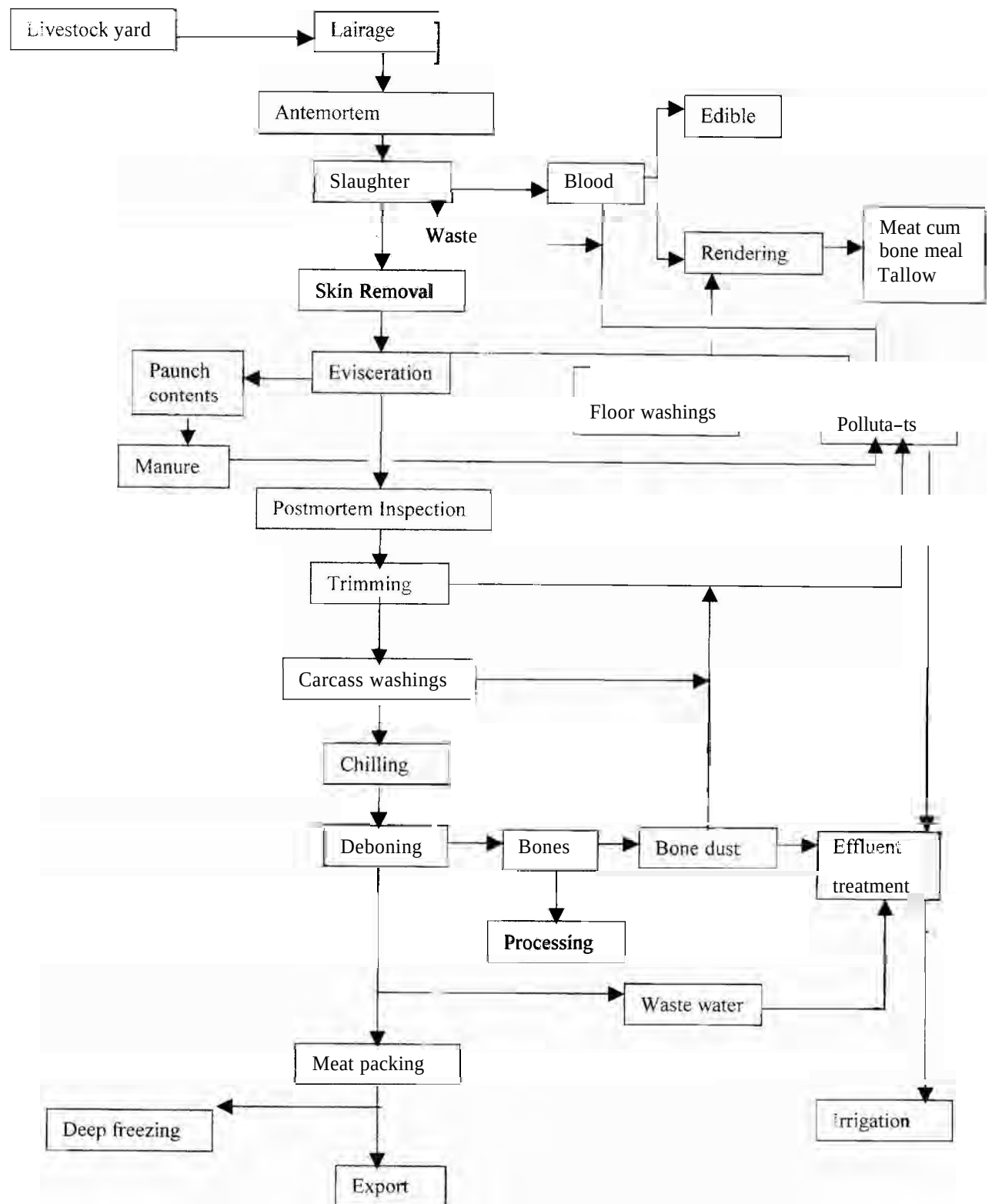


Fig. I. Flow chart for abattoir processes (meat, edible and inedible by-products)

HAEMORRHAGIC SEPTICAEMIA: CURRENT STATUS IN THE ASIAN REGION AND STRATEGIES FOR FUTURE CONTROL

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Abstract: Haemorrhagic septicaemia (HS) is ranked by most Asian countries as one among the infectious diseases that causes heavy losses in buffaloes and cattle. Since the disease occurs mainly in situations where husbandry methods are poor and therefore both disease reporting and control systems are poorly developed, the actual losses are considerably more than the reported losses. This fact has been established in active surveillance studies. It has also been well established that HS causes greater losses in buffaloes than in cattle.

Future control strategies should be built on the available epidemiological data. This includes the poor survival of the organism outside the animal body, the existence of a large percentage of latent carriers in endemic populations than was thought earlier, the conversion of such carriers into active shedders under certain circumstances and the persistence of the carrier status for long periods. Control measures should be directed towards prophylactic measures in endemic regions, restriction of spread during outbreaks, and controlling the spread across regional and national boundaries.

The key element in control is vaccination. While the vaccines presently available have to some extent succeeded in reducing losses, development of an ideal vaccine for production and use in HS endemic tropical countries and attaining a high vaccination coverage are of utmost importance. With an increasing involvement of the private sector in HS vaccine production, the need for Governments to lay down standards and maintain quality assurance is emphasised. Equally important is the operation of national HS control programmes, planned, and monitored centrally, with no financial burden on the resource poor owner-farmers. Current knowledge and limited experience does not appear to indicate the feasibility of eradication.

Keywords: Haemorrhagic septicaemia, carriers, control strategies.

Economic Importance in the Region

Most countries in the region recognise HS as a major cause of losses in buffaloes and cattle. In India during the period 1950's to 1980's the disease is reported to have accounted for 46% to 55% of all bovine deaths (Dutta *et al.*, 1990). It was also reported that during the period 1974 to 1986, HS accounted for 58.8% of aggregate bovine deaths due to five epidemic diseases, namely, rinderpest, black quarter, foot and mouth disease, anthrax and HS. In Pakistan, it is reported that 34.1% of all bovine deaths were due to HS (FAO 1979). Nepal ranks HS second only to rinderpest, as a killer disease of bovines. Another retrospective study of records in four districts in Nepal indicated that 24% of all bovine deaths were due to infectious diseases and that HS was the most important of these (Thakuri *et al.*, 1992). In an FAO-UNDP coordinated study in the Azad State of Jammu and Kashmir, it was revealed that whilst nutritional disorders and parasitism accounted for greater losses in livestock, HS and black quarter made the most significant losses due to infectious diseases. In Sri Lanka, a survey carried out in the 1970's in HS endemic areas revealed that approximately 15% of buffaloes died of HS before reaching adulthood and this accounted for two thirds of all buffalo deaths (De Alwis and Vipulasiri, 1980; Kumaratileke and Buvanendran, 1979).

Most estimates of economic losses take into account only direct losses i.e. value of animals that die. Other factors such as loss of draught power and the cost of alternate power, loss of potential productivity and reproductive capacity are not easy to estimate. Ahmed (1996) attempted to estimate at least part of the direct losses, by calculating the value of this loss by assuming the value of rice that was lost as a result of land left uncultivated due to non-availability of draught power. He estimated that direct losses accounted for only US \$ 2.3 million out of a total loss of

US \$ 148.6. In most countries of Southeast Asia too, HS ranks high among the infectious diseases of bovines

Susceptibility of the Buffalo

It is well recognised that HS affects buffaloes more than cattle, although few quantitative estimations are available. In Malaysia, it was found that 73% and 90% of all deaths caused by HS during the successive periods of 1970-79 and 1980-89 were among buffaloes, despite the fact that the buffalo population was less than half that of cattle, and was progressively on the decline during this period (FAO, 1979, 1991). In Sri Lanka, one study covering the endemic and non-endemic areas indicated that buffalo deaths were three times higher than in cattle (De Alwis, 1981). This difference in mortality rates was even more marked in the sporadic outbreaks in non-endemic areas than in regular outbreaks in endemic areas, where other factors appeared to mask this difference. Another study in Sri Lanka showed that whilst the percentage of buffalo herds infected was not markedly higher than for cattle herds and within infected herds, losses in buffaloes were significantly higher (De Alwis and Vipulasiri, 1980).

Why is HS a Problem?

Haemorrhagic Septicaemia is a bacterial infection. Only specific serotypes are incriminated and these have been identified. The organism is sensitive to a wide range of antibacterial drugs and vaccines incorporating the specific serotypes provide immunity. One wonders then, why HS has continued to remain a problem through the last few decades. There are many reasons for this situation.

HS is a disease whose prevalence is highest among the less well-managed, animals reared under poor husbandry conditions. In such situations, early detection of disease is difficult and treatment during this initial febrile stage is not practically possible. Treatment is thus of limited use, unless the clinically normal animals in affected herds are checked for elevated temperatures and treated immediately. Treatment during the later stages could even hasten death due to endotoxin shock. The *pasteurella* organism is a weak immunogen. This is evident from the poor immunity conferred by bacterins. Vaccines incorporating adjuvants are therefore used. Even among these adjuvanted vaccines the most popular and widely used vaccine is the alum-precipitated vaccine. This is undoubtedly due to the ease of preparation, handling and injection in the field. Yet, controlled trials have shown that this vaccine provides immunity lasting only for 3-4 months. The vaccine, which is widely proclaimed to produce high levels as well as long lasting immunity, is the oil adjuvant vaccine. Yet, on account of its high viscosity resulting mainly from the emulsifying agent (lanoline) used, very few countries use it widely. Most countries use this vaccine only for protecting valuable animals reared under good husbandry conditions.

Another reason for perpetuation of the problem is the low vaccination coverage. Whilst it is widely accepted that a coverage of at least 70% of the susceptible population should be attained for effective control, most Asian countries fall short of this target. Although in restricted areas high coverage may be attained, the national average in most Asian countries ranges from around 15% to 50% (FAO, 1979, 1991; ACIAR, 1993).

When HS breaks out in virgin areas, massive epidemics occur and these naturally draw the attention of the animal health authorities. When the disease becomes endemic, natural immunity is built up in herds due to frequent exposure. This mechanism has actually been demonstrated among free range animals (De Alwis and Sumandadasa, 1982; De Alwis *et al.*, 1986). In such situations, only a few hitherto unexposed young animals die each time, but such losses are of an insidious nature. Yet these losses occur with some regularity, the disease smolders among yearlings mostly and the cumulative losses are considerable.

Thus the perpetuation of the disease problem may be attributed to a combination of management and vaccination-associated constraints.

Current Status

The current status of HS in the Asian Region may be summarised as follows.

The disease occurs mainly among buffaloes and cattle, reared under poor husbandry conditions. Both the disease control systems and the disease reporting systems may not effectively reach such locations. Thus, the actual losses may be considerably more than those detected in passive reporting systems. This was amply borne out in a study in Sri Lanka (De Alwis and Vipulasiri, 1980).

Losses in buffaloes are higher than in cattle.

- Vaccination is practiced but, the common vaccines used are of poor quality and coverage of susceptible stock is low,
- Transport and movements of animals, particularly carriers from endemic areas pose the threat of spread locally and even across regional and national borders.

Strategies for Future Control

The current knowledge upon which future strategies could be developed are outlined below. The organism cannot survive in soil for more than a few hours. Dry conditions and exposure to sunlight hasten death, whilst moist conditions prolong survival. The same will apply to infected material. Unattended decomposing carcasses could be infective for a few days and carcasses dumped into rivers and washed ashore downstream can be an effective method of dissemination. No permanent reservoirs of infection are however established outside the animal body.

Following outbreaks, most clinically unaffected, exposed animals become latent carriers. The percentage of such carriers is much higher than was previously thought. In a field study, the proportion of such carriers was found to range between 12% and 40% (De Alwis *et al.*, 1986), and in a controlled exposure experimental study involving 57 buffaloes, 43 survived and 32 were shown to be latent carriers. This latent carrier state was found to persist in some animals up to 229 days, the longest period of investigation (De Alwis *et al.*, 1990).

These findings have an important bearing on the movement of animals from endemic to non-endemic countries or regions. It is important to determine for how long the region of origin was free of HS, before animals are moved out.

- It is of utmost importance that susceptible likely in-contact animals in the country of import be immune at the time of contact. This can be achieved only by vaccination.
- It should be considered that susceptible animals are mainly used for draught purposes and that a seasonal increase in occurrence of outbreaks is observed during the wet season, presumably due to the interaction of a variety of weather-related factors.
- Owner farmers are resource poor, and can ill afford to pay for vaccines.

Strategies for future control could be grouped into three categories. These would include prophylactic measures in endemic countries, measures to prevent spread during outbreaks and those to prevent spread across regional and national borders.

Prophylactic Measures in Endemic Countries

These measures include the following:

- Routine prophylactic vaccination. The spread of HS being largely influenced by wet season-associated factors, routine prophylactic vaccination is best timed for 3-4 months before the wet season so as to ensure peak immunity during the high risk period. Vaccination of cows in the early third trimester of pregnancy is also encouraged in farm herds to provide immunity to the young calves.
- Establishing good disease reporting systems. This is an extremely important aspect of control, not only to bring the control measures into operation early, but also to help authorities to obtain a more accurate estimate of the losses. Resource allocation for HS control will evidently depend upon the recognition of the actual magnitude of the problem.
- Creation of an awareness among farmers. This should also encourage farmers to notify the disease control authorities, when HS is suspected.
- Prevention of contact between animals from endemic and non-endemic areas. This is important in countries where distinct endemic and non-endemic areas exist. In endemic areas, a large proportion of animals have been found to be latent carriers (Re Alwis *et al.*, 1986). These animals are potential sources of infection and if activated and become shedders could infect in-contact susceptible animals. In such situations, if animals from non-endemic countries are unvaccinated as they often are, herd immunity is negligible (De Alwis and Sumanadasa, 1982) and explosive outbreaks may result.

Preventive measures during outbreaks

These measures are well established and will only be briefly mentioned here.

- Vaccination in the face of outbreaks, irrespective of previous vaccination history.
- Observation, detection, isolation and treatment, where possible of clinically affected animals and checking the rectal temperatures of in-contact animals and treatment of those showing elevated temperatures.
- Search for sick animals and carcasses in free roaming herds.
- Proper disposal of carcasses, unconsumed fodder, bedding etc., from infected premises.
- Immediate notification of animal health authorities, and collection and dispatch of material to diagnostic laboratories"
- Close monitoring of animal movements and total stoppage of movements and confinement of herds where necessary.

Prevention of spread across borders

One has to consider the spread across regional borders within countries as well as across national borders. The former is more important than is often thought to be, since most Asian countries have endemic regions or pockets. When spread across national borders is considered a number of complexities arise. The island situation is distinctly different from land borders. Then, in addition to the problems arising from the long term carrier status that might render normal quarantine procedures ineffective, one should also contend with the illicit movement of animals across national land borders not uncommon in the Asian continent.

Vaccines

Vaccination remains as the key element in any HS control program. The vaccines currently used, their strengths and weaknesses and the problems in attaining high coverage has already been dealt with. The ideal vaccine against HS for use in Asia should have the following features.

- It should provide a high level of immunity for at least one year.
- It should be easy to administer to animals, particularly buffaloes.
- It should be stable and lend itself to easy handling under tropical conditions.
- It should produce no adverse effects.

- It should be easy and economical to produce
- The production technology should be sustainable in the HS endemic countries of Asia.

None of the vaccines produced so far satisfy all of these requirements. Thus, research is constantly being carried out towards achieving this goal. Some of the areas in which research potential exists, or has actually been done is described below.

- **Improving the immunogenicity of the bacterin component:** a large volume of work has been done in this area and the general consensus is that (a) many cell components contribute towards total immunity and (b) certain cell components such as some outer membrane proteins (OMP's), which are produced *in vivo* make a significant contribution (Penn and Nagy, 1976; Muniandy and Mukker, 1993; Veken *et al.*, 1994, 1996). Thus formulating growth media which will enhance full expression of all immunogenic cell components in *vitro* will be a useful area for future research.
- **Improving the formulation for oil adjuvant vaccine:** The primary aim of this exercise would be to reduce its viscosity and thereby facilitate injectability. Many countries such as Sri Lanka and Indonesia have successfully achieved this to some degree by lowering the lanolin content to 4 - 6.5%, without substantially compromising with stability. Other oils and emulsifying agents have been successfully used in Pakistan and Thailand, although some of these are as yet only at the experimental production level (Muneer *et al.*, 1994; Atthi *et al.*, 1997).
 - Double adjuvant vaccine: In Malaysia an effort has been made to concentrate the bacterin prior to emulsification by combining the principles embodied in the alum precipitated and oil adjuvant vaccines. This has helped to reduce the dose volume (Chandrasekaran, 1996).
 - The principle of double emulsion: For thinner free-flowing vaccines, this principle has been used successfully on an experimental scale in India and Malaysia. The large scale production technology has yet to be developed (Mittal *et al.*, 1977-1979; Yadev and Ahooja 1983; Chandrasekaran *et al.*, 1994).
- **Live vaccine:** These are based on immunogenic strains that protect against the Asian HS serotype B:2 administered by injection or as an aerosol, with no risk of disease.

Potentially, there are four types of organisms that can be used. These are as follows:

- Serologically related serotypes: The type B:3,4 vaccine based on a deer strain has been successfully used in Myanmar as an aerosol. This vaccine however is not safe for intramuscular injection to young buffaloes. (Myint and Carter, 1989; Carter *et al.*, 1991; Myint, 1996)
- Vaccines based on naturally occurring mutants or variants. Although records of isolation of several such strains appear in the literature, no investigations have been done on their use as vaccines. The Indian paraplegia strain designated M 25 (Dhanda and Nilakanthan, 1961) and the ATCC 19427 are examples. These strains need, in the first instance to be re-examined in the light of more recent serological methods and molecular techniques.
- Induced mutants: These are mutants selected for avirulence after exposure to irradiation or chemical mutagenic agents. The streptomycin dependent strain used experimentally in Sri Lanka (De Alwis and Carter, 1980), and a low virulent streptomycin independent revertant R 39 used by De Alwis *et al.*, (1996) are examples of this type. Neither of these led to the development of practical vaccines.
- Genetically engineered mutants: This would imply identifying the virulent factors and the genes responsible for their expression, without interfering with immunogenicity. No such strains are yet on record. However, the advent of molecular biology, has brought this area within the realms of possibility.

Molecular biological techniques have also helped to discriminate between strains of the same serotype, and identification of dominant types may provide a more rational basis for the selection of future vaccine seed cultures (Townsend *et al.*, 1997 a,b; Rimler, 2000)

Field workers and vaccinators have diverse views on the vaccine administration techniques. Although it is generally acclaimed that aerosol vaccines are easier to administer, animals yet need to be restrained. Some vaccinators believe that a jab on the back is easier than administration of a puff directed to the nostrils from the front. It is therefore preferable that any live vaccine should lend itself to easy administration by either method.

Eradication?

Although much has been spoken of eradication, the only attempt made was by Indonesia, in the Lombok Island with a cattle and buffalo population of 300,000. After 7 years of mass vaccination, covering over 90% of the stock, the disease still continues to be present (Syamsudin, 1993)

Thus the strategy for future control would rest heavily upon,

- Effective reporting and monitoring.
- Monitoring of animal movements.
- Research and development of better vaccines and
- Achieving higher vaccination coverage, through national disease control programmes.

Vaccination programmes

Vaccination programmes should take into account the season of maximum disease occurrence as well as the period of utilisation, hence availability of animals for vaccination. Coverage of at least 70% should be attained. Vaccines should reach the animals free of charge to the resource poor owner-farmers. Vaccination should not be left as a voluntary activity but should be an organised National Immunisation Programme.

Vaccines have been produced in the past exclusively by governmental organisations. During the past decade or so, in a few countries viz India, Philippines and Indonesia, private organisations have stepped into this activity. This trend may continue at an accelerated pace in the future, in the region. The government should however enforce standards and continue its role in quality testing.

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BUFFALO AS A DRAUGHT ANIMAL WITHIN SMALLHOLDER FARMING SYSTEMS IN ASIA

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Abstract: At the present, draught buffaloes are still an essential component in smallholder farming systems in developing countries, especially in Asia. Although buffalo populations in Asia in general, had positive growth rates during the years 1991 to 1997, those in some countries dropped drastically due to the reduced use of buffalo draught power as well as the increase in beef consumption. Information relating to the utilisation of draught buffaloes within rural economies of developing countries is presented. Scientific evaluation of the working efficiency of buffaloes can be made by the measurement of the draught power and work output in the field. Some factors affecting draught capacity of buffaloes i.e. harnessing systems, sex, age and size of buffaloes, breed types and meteorological conditions, are reported. Since small farmers in the rural areas have adopted some degree of mechanisation, future prospects for the use of draught buffaloes and mechanisation are also discussed.

Keywords: Buffalo, draught animal, work efficiency, draught capacity, small farms,

Introduction

For people who live in cities, especially those in developed countries, it is hard to imagine that in today's world of highly advanced science and technology, more than 2,000 million people in developing countries still depend on draught animal for work on traditional farms and for transportation. The use of draught animal power (DAP) on rural farms remains a common practice, despite the promotion of farm mechanisation by governments of various countries (Chantalakhana and Bunyavejchewin, 1994). Buffaloes are one of the most useful draught animals in the world, with a total of over 140 million in more than 50 countries in 1900 (Chantalakhana and Skunmun, 1999). Almost 96% of buffaloes were found in the Asia and Pacific region, where most buffaloes were raised by small farmers in developing countries for draught as well as for beef and dairy purposes.

Table 1 shows buffalo populations during the period 1989/91 to 1997, and their average annual growth rates in some Asian countries (FAO, 1997), where the use of draught buffalo power is very common. It reflects in general a positive growth trend of the buffalo populations in most of these countries. However, there was a reduction of buffalo numbers in some countries. The countries with significant buffalo populations and showing negative growth rates were Malaysia (-4.5%), Thailand (-3.7%) and Indonesia (-0.8%) in Southeast Asia. In South Asia, a 2.8% reduction in buffalo numbers in Sri Lanka has been reported during the same period. The decreases were due to various causes such as lack of grazing land, increase in the use of farm mechanisation, high rates of buffalo slaughter, increasing demand for beef, and growth of the human population (Bunyavejchewin and Chantalakhana, 1991). Ninety-five to 99% of swamp buffalo production systems in China and Southeast Asian countries can be classified as smallholders or small enterprises, in which buffalo raising is not regarded as a distinct enterprise, but rather as an integral part of crop production systems (Chantalakhana, 1996). The swamp buffaloes primarily provide a source of farm power for tillage and transportation and a source of manure for fertilizer, while meat and milk are secondary products in these systems. The most common places where buffaloes play a prominent role are the rice-production areas. Draught power from the swamp buffalo is commonly used in lowland rainfed rice production systems, while irrigated rice cultivation usually employs farm machinery. Swamp buffaloes are also used wherever available in cultivation of rice and other crops in upland areas. In China and many countries in Southeast Asia, draught animal power remains an important source of the energy input per unit of cultivated land, in spite of the increasing use of petroleum-based power in

particular regions of some countries. It has been reported that swamp buffaloes provide 20 to 30 per cent of the farm power in South China, Thailand, Indonesia, Malaysia, the Philippines and Indonesia (Chantalakhana, 1988). In traditional South Asian agriculture, the small farmer is basically a crop farmer. Buffaloes are maintained generally for draught power to carry agricultural operations mainly in Sri Lanka and Bangladesh (Soni, 1991).

Table 1. Buffalo population in some Asian countries during the year 1989-91 to 1997.

Country	Buffalo No, (1000 head)				Average annual growth rate (%) (from 1989-91 to 1997)
	1989-91	1995	1996	1997	
PR Chins	21412	22928	23315*	23518*	1.6
SE Asia					
Cambodia	743	765	770	770E	0.6
Indonesia	3297	3112	3140	3140F	-0.8
Laos	1067	1191	1212	1212F	2.3
Malaysia	206	157	150	150F	-4.5
Myanmar	2051	2203	2266	2297	2.0
Philippines	2751	2708	2841	2968	1.3
Thailand	5152	3710	4000F	4000F	-3.7
Vietnam	2861	2963	2954	2954F	0.5
South Asia					
Bangladesh	771	882*	821	854	1.8
India	80577*	88759"	90762*	92190*	2.4
Nepal	3020	3278	3302	3362	1.9
Pakistan	17377	19711	20200	22000F	4.4
Sri Lanka	917	764	761	761	-2.8

Note *unofficial estimates, F - FAO estimates

Draught Buffaloes and the Rural Economy

About 75-80% of people in developing countries are engaged in agriculture, most of them smallholders with two to three hectares per household, but many remain landless. The small holders grow crops as their major source of food and income, while animals including buffaloes, cattle, pigs and poultry are integrated in the farming systems to provide supplementary income, food and services such as draught power. Over the past few decades, there have been many unsuccessful attempts to introduce these farmers to modern agriculture, and numerous problems of small farm development remain to be resolved. Small farmers are most commonly plagued by hunger, poverty and lack of education, which are chronic problems of developing countries. As long as there exist small farm agricultural systems in developing countries, DAP will remain one of the most important sources of farm power. In the foreseeable future, although the rate of urbanization is increasing, rural small farmers will continue to form a significant proportion of the population in developing countries.

Is the use of draught buffaloes really such a backward method of farming?

Those who have worked closely with small farmers will be able to reply immediately that this is not true. In fact, the use of draught buffaloes on small farms is ecologically and environmentally sound, technically quite appropriate, economically viable and socially and culturally desirable. The sustainability of small farm production depends significantly on the availability and efficient utilization of draught power from buffalo, either as a major source of farm power or complementing tractors and human labour. The use of draught buffalo for land preparation in crop production has been traditionally practised by rural farmers since time immemorial, without any serious evidence on environmental degradation, air or water pollution, or soil depletion and compaction. On the contrary, buffalo manure has been used by rural farmers as fertilizer, so that the productivity of crops such as rice has been maintained for centuries without the use of any

chemical fertilizer. Buffaloes are raised with hardly any external cash inputs, being fed mainly with weedy grasses or plants and crop wastes, such as straw or leaves, or with by-products such as bran or broken rice. These feeds are available on farm and are generally not easily marketable for various reasons,

Buffaloes turn farm wastes and by-products into valuable assets for farmers, providing not only draught power but also meat, milk and a relatively large cash income every time an animal is sold. From a socioeconomic point of view, these buffaloes serve as long-term savings account for rural families, most of whom would never deposit cash in a bank. In the case of crop failure, due to natural causes such as flood, drought or pests, the sale of a buffalo provides enough cash to purchase an year's supply of rice for one family. Hence, the buffaloes serve as an insurance against crop failure, especially in small farms where risks and uncertainties are common features under rainfed conditions. Furthermore, buffaloes are occasionally sold or slaughtered for meat on special traditional events such as at the wedding of a son or daughter, the entry of a son into a Buddhist monastery, or in other significant religious ceremonies. Buffaloes are also regarded as good companions for village people, especially children and the elderly. They are often used in recreational events such as buffalo racing or fighting, which are tourist attractions in some countries.

Draught power

Draught power in animals is measured by the use of sophisticated instruments, for more accurate assessment of working efficiency. It involves the measurement of two components i.e. draught force and speed, which are negatively correlated to each other. Buffaloes of 400 to 900kg body weight can produce draught power equivalent to 0.75 horse power (hp) as compared to 1 hp from a light horse of 400 to 700 kg body weight (Cockrill, 1974). Under normal conditions, buffaloes appear to move more slowly than horses, mules or donkeys, but they are efficient in muddy or flooded land, such as paddy fields.

A mature buffalo can develop a tractive power of 10 to 14% of its body weight under normal working conditions (Coe and McDowell, 1980). Under rainfed lowland condition in the Philippines, draught power generated by buffaloes for ploughing was on the average 0.43 to 0.54 kilowatt (Sarabia *et al.*, 1996a). With regard to breed types of buffaloes, Philippine carabao (PC) used more power than Philippine carabao x Murrah (PM) and Cambodian buffalo x Murrah (CM) crossbreds in ploughing under the same area (0.54, 0.46 and 0.43 kilowatt for PC, PM and GM, respectively), and draught force developed by PC, PM and CM was 14.73%, 14.68% and 11.65% of the body weight, respectively [see Table 2). In other words, the working efficiency of CM crossbred seemed to be better than the other breed types. The use of draught power of buffaloes in Thailand, for different tasks on different soil types on smallholder farms is shown in Table 3 (Chantalakhana *et al.*, 1991). Although the number of observations was small, there was an indication from the findings that buffaloes generated more power during first ploughing than during second ploughing, while more power was required for ploughing on clay than on other soil types. In the same soil types, it was notable that buffaloes of different sizes generated similar power, but their work output in terms of area ploughed was greater with smaller buffaloes. Similar to the findings of Bunyavejchewin *et al.* (1986), smaller buffaloes significantly generated less power than larger ones in carting the same load.

Working ability of buffaloes

People who are not familiar with the buffalo often assume that the animal is wild, dangerous and lacking in intelligence, but this is not true. On the contrary, buffaloes on small farms are quite tame and can easily be trained to do farmwork using various implements such as ploughs, rakes, water pumps, sugar cane crushers, sledges and carts. Draught buffaloes can be trained to respond to a pull on the rope or the human voice, and can be tended by children, women or elderly people.

Table 2. Draught performance of the buffalo breed types under rainfed lowland condition in Ubay, Bohol, the Philippines

Items	Breed types		
	PC	PM	CM
Numbers of animals	4	4	4
Pull, kN	0.74	0.71	0.69
Draught force, kN	0.69	0.67	0.66
Speed, m/sec	0.79 ^a	0.70 ^b	0.66 ^b
Draught power, kW	0.54 ^a	0.46 ^b	0.43 ^b
Draught power, hp	0.73 ^a	0.62 ^b	0.57 ^b
Average body weight, kg	474.50	458.00	570.50
Draught force as % body weight	14.72 ^a	14.68 ^a	11.65 ^b

Source: (Sarabia *et al.*, 1996a)Note: Figures with different superscripts in the same row are significantly different ($P < 0.01$)

PC - Philippine carabao. PM - Murrah x PC. CM - Cambodran buffalo x Murrah

Table 3. Measurement of draught power of buffaloes in three soil types

Tillage	Soil type	Buffalo wt. (kg)	No.	Power (kW)	Draught		Area ploughed (m ² /h)
					Force (kg)	Speed (km/h)	
1"	Sandy loam	340 (S)	7	0.23	25.5	3.5	769
		412 (M)	17	0.24	32.1	2.7	526
		457 (L)	1	0.23	30.9	2.7	393
1°	Clay loam	413 (M)	4	0.27	33.3	2.9	437
2"	Sandy loam	423 (M)	1	0.21	27.9	2.2	731
		452 (L)	1	0.15	19.1	2.8	807

Source: (Chantalakhana *et al.*, 1991)

Note. S = Small (<376 kg), M = Medium (376-450 kg), L = Large (>450 kg)

The amount of work performed by draught buffaloes varies from place to place and depends on the season and farming systems (Table 4). In general, male buffaloes are preferred because they are bigger and have proportionately greater working efficiency. But because of an increasing shortage of draught buffaloes during recent decades in some Asian countries like Thailand, both male and female buffaloes have been used for work, including pregnant female buffaloes (Bunyavejchewin *et al.*, 1995b).

The data collected on the use of individual buffaloes for farmwork, from village households over a period of an year, in Northeast Thailand show that draught buffaloes are used on average for 51 to 69 days per year, within a range of 8 to 115 days (Chantalakhana *et al.*, 1991). Two to three buffaloes can supply animal traction for a farm of 2-3 ha. The same study has shown that buffaloes are used most intensively during July and August, which are the months when the most ploughing and planting take place. Similarly in Indonesia, it has been shown that the intensity of work by draught buffaloes varies widely from one farming system to another, the number of work days per year ranging from 10-30 days in rainfed rice production to 200-300 days for cart haulage (Petheram, 1991). It has also been pointed out that in Indonesia, DAP is most important in farming systems that are isolated from infrastructural facilities and have a high ratio of land to population. It is also interesting to note that female buffaloes are more commonly used for work than males in most farming systems in Indonesia, which is related to the dual function, i.e. work and reproduction, of the females.

Table 4. Buffalo draught activities and average time required per year in some Asian countries

Activity	Days/head	Hours/day	Hours/yr	References
Ploughing	44-47		110-111	Thailand
Raking/harrowing	21-26		16-29	(Chantalakhana <i>et al.</i> 1991)
Carting	6-20		14-40	
Total work	51-69	5	133-169	
Land preparation (paddy)				Indonesia (Petheram, 1991)
¹ crop/yr (rainfed)	10-30	3-5		
2 crops/yr (irrigated)	25-60	3-6		
3 crops/yr (irrigated)	60-90	3-5		
Carting (up to 30 km/d)	200-300	0		
Agricultural work	80-100			Philippines (Momongan, 1992)
Tillage (paddy)	30-120	7-8		PR China (Yang, 1995)
Agricultural work	52	7		Sri Lanka (Ranawana, 1991)
Agricultural work	86	5		Nepal (Oli, 1991)
Rural transportation	55	—		

It has been reported in the Philippines that buffaloes of both sexes are used for work on an average of about 80 to 100 days per year (Momongan, 1992). In the Peoples Republic of China, the average total work days of buffaloes in rice growing areas per year is between 90 to 120, with the intensive working period falling in the spring and autumn, when draught buffaloes have to work as long as 7-8 hours a day (Yang, 1995). In South Asia, the average total work days of buffaloes for agricultural work is 56 and 86 in Sri Lanka (Ranawana, 1991) and Nepal (Oli, 1991) respectively.

Factors Affecting Draught Capacity of Buffaloes

In general, work production from buffaloes or any other draught animals is not a tangible commodity like meat or milk. There are such factors influencing working efficiency of buffaloes, as harnessing systems, types of work, soil types, existing environment as well as sex, size, age and breed of buffaloes. The common measurement for working efficiency of animals in the field is conducted in terms of an amount of work output within a period of time e.g. area ploughed, the amount of water lifted. etc.

Harnessing systems

In Asia, the neck yoke is the most common harness used for buffalo either singly or in pair. The yoke is normally a wooden crossbeam either straight or elliptical in shape, depending on the implement drawn. A rope tied at both ends is passed under the neck. Garner (1957) has pointed out two disadvantages of this method of harnessing buffalo. One is that the rope under the throat is pulled tight against the buffalo's windpipe, restricting its normal breathing function. Thus, the air-oxygen intake is reduced and fatigue sets in within a very short period of time after the animal has begun pulling the load. Another is that the yoke, which is in contact with only a small area of the buffalo neck or withers, digs into the flesh when a heavy load is pulled and causes discomfort. A collar or a breast strap used in Thailand for almost 40 years has been shown to increase buffalo ability in ploughing and har-owing by 25%. Although better technology in harnessing systems of the buffalo has been developed, Asian farmers for unknown reasons have not adopted these. Some of the limitations could be the lack of effective technology transfer or the availability of materials to produce the collar or the breast strap.

Sex, age and size of buffaloes

Little information is available on work output of buffaloes as influenced by sex, age. The findings of Chantalakhana *et al.* (1991) and Bunyavejchewin *et al.* (1995a) revealed that under real farm conditions in North-eastern Thailand, the size and age of buffaloes were highly related to their

draught capacity. As far as the age animals was concerned, buffaloes at younger age (4-5 years) were able to plough larger area during the first tillage compared to buffaloes at higher age (6-10 year-group and older than 10 year-group) on both sandy loam and clay loam (Table 5). However, during the second tillage when work was lighter, the older buffaloes tended to perform better than the younger buffaloes on sandy loam, but not on clay loam. Bunyavejchewin *et al.* (1995a) indicated that the younger animals though smaller in body weight could achieve better work efficiency as compared to older animals especially during the first tillage when more power would be required to plough the more compact soil surface. For buffalo size, work efficiency of village buffaloes as reported by Bunyavejchewin *et al.* (1995a) shows that smaller buffaloes tended to work more efficiently than larger ones in terms of area ploughed, especially with heavier work like at first tillage on sandy loam and clay loam (Table 6). Similar findings were reported by Chantalakhana *et al.* (1991). Due to the limited number of male buffaloes available for on-farm study, the findings on differences in working capacity between male and female buffaloes in Thailand were not conclusive. The availability of other information as of today is very limited both for male and female buffaloes.

Table 5. Work output of buffaloes at different ages.

Type of work	Soil type	Age (years)	Ave. body wt. (kg)	No. observed	Ave. area ploughed (m ² /h)	C.V. (%)
1 st tillage	Sandy loam	4-5	381.76	5	594.59	14.43
		6-10	424.62	14	420.66	40.11
		>10	437.24	11	439.06	29.53
	Clay loam	4-5	395.50	3	475.37	38.24
		6-10	434.10	7	381.99	37.11
		>10	425.33	3	282.20	5.71
2 nd tillage	Sandy loam	4-5	394.73	8	860.40	60.39
		6-10	411.48	13	705.13	64.13
		>10	430.33	8	990.25	47.35
	Clay loam	4-5	380.25	2	546.79	0.69
		6-10	417.24	9	649.85	69.98
		>10	459.30	2	431.50	1.57

Source. Bunyavejchewin *et al.* (1995a)

Breed types

Buffaloes are used as multi-purpose animals in the Southeast Asian countries, i.e. for draught, meat and milk, crossing swamp buffalo with riverine buffalo has been conducted in PR China, the Philippines and Thailand. It was evident in PR China that the swamp x Murrah crossbreds (SM) had better ploughing performance than swamp buffaloes (Yang, 1995). In contrast to the findings of Konanta *et al.* (1986), swamp buffaloes in Thailand could significantly plough more land than SM crossbreds under the same environmental conditions. A comparative study of the Philippine carabao (PC), PC x Murrah (PM) and the Cambodian buffalo x Murrah (CM) during a 12-day field situation was evaluated (Sarabia *et al.*, 1996a). The ploughing ability of the PC (618 m²/h) was significantly higher than that of PM (575 m²/h) and CM (475 m²/h). The effects of breed type of buffaloes on work output are inconclusive.

Meteorological conditions

Due to physiological limitations of buffaloes to hot weather in Asian region, farmers in general have traditionally limited the use of buffaloes to the early morning or the late afternoon hours to avoid heat stress in buffaloes. The working capacity of buffaloes tends to relate to time period during the day. During the hottest hours (1:30-2:30 p.m.) in Thailand, the performance of buffaloes in turning a water pump was significantly less efficient than during other time periods (7:30-8:30 am, 9:00-10:00 am, and 3:00-4:00 p.m.), in terms of revolutions per minute (Bunyavejchewin *et al.*, 1985). In the Philippines, it was found that when work started at 3:00

p.m. onwards, the area ploughed by buffaloes was larger than when started at 7:00 am or 7:30 am onwards, while ambient temperature still progressed (Sarabia *et al.*, 1996b). However, the efficiency of buffaloes in terms of work output was not shown in different time periods, during one hour of work, but the time periods did affect physiological traits of buffaloes (Bunyavejchewin *et al.*, 1991; Sarabia *et al.*, 1996b).

Table ti. Work output of buffaloes classified by sizes.

Type of work	Soil type	Size	Ave. body wt. (kg)	No. observed	Ave. area ploughed (m ² /h)	C.V. (%)
1 st tillage	Sandy loam	S	354	3	507	5.90
		M	407	20	445	6.38
		L	506	5	441	12.84
	Clay loam	S	353	2	671	8.19
		M	403	7	336	4.46
		L	531	4	377	13.18
2 nd tillage	Sandy loam	S	358	5	818	4.75
		M	404	19	846	5.20
		L	508	5	799	6.69
	Clay loam	S	351	3	852	5.98
		M	396	9	687	3.53
		L	520	3	574	7.88

Source: Bunyavejchewin *et al.* (1995a)

Note. S = Small (< 376 kg), M = Medium (376-450 kg), L = Large (>450 kg)

Future Prospects for DAP and Mechanisation

In several developing countries, the numbers of small tractors on farms have been increasing steadily, due to promotion by both the government and private companies. This has led some people to believe that the use of DAP might soon be replaced by mechanisation. However, from actual experience during the last three decades, it is clear that such simple extrapolation is not correct in many situations, except in some irrigated areas in certain countries. Some analytical assessments that have been done at farm or village level indicate that because individual holdings are so small, it is not economical for each farmer to own even a small tractor. When they do, they use it on their own farms for only 40-50 hours a year, because they have little land and insufficient water to grow crops outside the rainy season. At least 240 working hours per year are required to make the use of a small tractor economical. These farmers hire out their tractors to their neighbours during the remainder of the time (Chantalakhana and Bunyavejchewin, 1994). Apparently, in villages where there are both small tractors and draught buffaloes, many farmers use both DAP and a tractor, others use only DAP, while others use only a tractor for farm work, but keep buffaloes as saleable assets.

From macro-level analysis, it has been recognised that numerous factors besides the availability of mechanised farm tools affect the sustained adoption of petrol power by farmers. These include the availability of irrigation water, the market price of crop products, the improvement of village infrastructure such as roads and electricity, the existence of off-farm job opportunities for villagers, government agricultural policies and other economic developments, such as industrialisation and the expansion of tourism (Bunyavejchewin *et al.*, 1993; Sabrani, 1993; Chantalakhana, 1994).

The use of buffaloes on small farms in developing countries is definitely not a backward system of farming. However, it certainly needs effective and sustained support by research and development agencies so that it can be improved, not only from a biological point of view but also with regard to engineering, socio-economic and political aspects,

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PLENARY SESSION - II

Buffalo as a Multi-purpose Animal within Farming Systems of Asia

Discussion

Q. L.C. Cruz - There has been a discussion about the impact of technologies particularly on small farmers and there is agreement that when the management level is very low, the greatest impact can be obtained by improving nutrition rather than genetics,

A. S.K. Ranjhan - I would like to give an up-date on the use of UMMB in India. The ruminant has been dubbed as an animal that produces more methane than other animals, When UMMR is given with poor quality roughages, the methane production is reduced and therefore environmental pollution is reduced. In India UMMB was first given in Gujarat and Maharashtra States. There were many problems and farmers did not accept it because of the manner in which it was dispensed. Many of the animals would eat much more of the block than required. The main principle involved in giving the UMMR was to allow the slow release of ammonia when animals lick the block. This did not happen. So they cut the block into required amount and fed it twice a day. But this defeated the principle of slow release. So another product was developed, which was the UMM granules so that there was a slow release of urea. This was well accepted by farmers.

Q. A.N.F. Perera - When the granules were fed twice a day, what was the rate of release of ammonia? Was the urea in the same form or as biuret?

A. S.K. Ranjhan - If you wish to have more information, I could give you the names of the scientists working on this. They have reduced the urea content from 10% to 5% and at this level, the required level of rumen ammonia was maintained.

Comment: A.N.F. Perera - We tried the same method by feeding twice a day in the form of a bolus and monitored the urea ammonia levels in the rumen. The ammonia level gave a very high peak in 3 - 3.5 hr. and then declined to the required level of 200- 250 mg/l. This level was maintained for about 6-7 hr until the second bolus was given.

Q. Anon. - What is the basis of fixing the price of buffalo milk in Italy.

A. A. Borghese - The basis is the demand, because all the buffalo milk is processed into Mozzarella cheese and it is very popular, We require more milk to increase production for export.

Q. ? Skunmun - I am getting old now, so I would like to know the composition of Mozerella cheese.

A. A. Borghese - The water content is about 45 %. In this case we sell water and cheese. I can say that Mozerella has the highest price of cheese in the world, when you compare the cheese as dry matter. There is no problem with cholesterol, because you cannot eat 1 kg or 3 kg of Mozerella cheese. If you consider the water content you will eat less mg, of cholesterol than if you eat butter or animal fat.

Q. A. Borghese - I visited Haryana and Rajasthan in North India. I noted that half the population is vegetarians and the other half, eats chicken. How is it possible to collect all the buffaloes that are distributed in far locations?

A. S.K. Ranjhan - In India 75% are non-vegetarian, Most eat chicken and lamb. Only Muslims eat buffalo meat. Twenty years ago we had 50% buffaloes and 50% cattle. Now we have 85% bufaloes and 15% cattle. This is because farmers are concerned when a male calf is born to

his cow, he cannot sell it for slaughter and they have a problem. But if a male buffalo calf is born they can sell it for slaughter, because there is no religious taboo on the slaughter of buffaloes. We have 100,000 farmers registered with us. As soon as the calf reaches 200 kg and above, our network of suppliers collect and truck them to the company.

Q. A.D.N Chandrasiri - Cattle are considered as holy animals. When people get to know that you are slaughtering buffaloes would they not create problems? What type of slaughter practice is adopted and is the Halal slaughter adopted?

A. S.K. Ranjhan - Yes, we have some problems. People show concern about slaughtering cows. But no cows are slaughtered and also the Company plays this on a low key. Our extraction rate is about 7% now, but we can go higher. We have adopted humane slaughtering practices and they are slaughtered by the Halal method. Animals are made unconscious first and then they are slaughtered.

Q. D.D. Cunawardena - There is a common belief that animals that die of HS in the field are the best animals. Is there any basis for this belief?

A. M C.L. de Alwis - Generally, a specific age group is affected, those between 6 m and 18 m of age.

Q. B.M.A. Oswin Perera - Can carrier status in animals be eliminated by treatment with antibiotics

A. M C.L. de Alwis - No. It has been experimentally established that organisms are lodged in the tonsils which antibiotics cannot reach.

Q. O.P. Dhanda - As a result of the current changes in the market and economic conditions, small holder farmers are switching over to mechanisation. They resort to hiring tractors. The period of the usefulness of the buffalo throughout the year is limited. In this situation, the question is why should small holders maintain buffaloes?

A. P. Skunmun - I agree that the conditions are changing rapidly. This is happening in Thailand also, but small holders come back to the draught animal because of is not only draught power that the poor farmer is interested in, but also in income generation.

Q. M Thangarajah - Have you done any comparative studies on draught power with cattle?

A. P. Skunmun - The buffalo is a marvelous animal in paddy lands. Cattle are good for dry land, For this reason we have not carried out comparative studies.

Comment. S.S.E Ranawana - The yolk of the harness used is unsuitable and disturbs the animal. New harnesses need to be developed to make the buffalo more efficient.

Comment, H, Makkar - I agree with Dr. Skunmun that one of the reasons why small holders keep livestock is that in times of financial difficulty, they can sell the animals.

THE CURRENT SITUATION OF BUFFALO PRODUCTION IN INDIA

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Abstract: India has 82 million buffaloes that are mostly used for milk and meat production. The role of the buffalo as a draught animal has declined very fast due to mechanization of agriculture and increased use of cattle for draught purposes. There is a shift in the buffalo farming system towards milk production, with the result that in the three Northern States of India, namely, Punjab, Haryana and Uttar Pradesh, buffaloes account for 75 to 90% of the bovine population. In future, buffaloes will be used as dual-purpose animals for milk and meat production in India.

There are 15 distinct buffalo breeds that account for 20% of the buffalo population, whereas 80% of buffalo population is still of the nondescript type. The upgrading of the nondescript buffaloes with the Murrah breed, has been initiated in many States to improve the milk production. India produces about 32 million tonnes of milk and 1.2 million tonnes of meat from buffaloes. Feeding lots for buffaloes have not yet been established, but efforts in this direction are being made.

Introduction

Livestock forms **one** of the important sub-sectors of Indian agriculture. Sustained growth in the livestock sector has made a beneficial impact by generating employment and reducing rural poverty. More than 650 million people (65% of the population) live in the rural areas. Of the total number of households about 73 percent own livestock. The income from livestock production accounts for 15–40 percent of total farm household incomes. Small and marginal farms account for 75% of these households, raising 56 percent of the bovines (cattle and buffaloes), and 62 per cent of the sheep population.

Among the livestock sector, **cattle** and buffaloes play an important role. In 1995, India accounted for 15 percent of world cattle population and 53% of buffalo herds. The cattle and buffalo population in India is given in Table 1.

Contribution of the buffalo in **milk** and **meat** production

Buffaloes in India are mostly used for milk and meat production. The role of the buffalo as a source of draught animal power is declining very fast due to mechanization of agriculture and increased use of cattle for draught power. This shift in the buffalo farming system towards milk production is because the buffalo is now emerging as the major milk and meat producing animal in India.

Milk Production

Buffaloes are now used in many countries to provide draught, milk and meat, but the domestic buffalo remains essentially an Asian animal. Table 2 shows the buffalo population in India in relation to the world population and some selected countries in the Asian regions. The table also gives the milk and meat production data, India with 53 per cent of the world's buffalo population, produces 64% of the world buffalo milk production,

Buffalo milk has higher fat and calcium contents. Buffalo milk fat has less cholesterol and more tocopherol, which is a natural anti-oxidant. Buffalo milk is ideal for making Mozzarella cheese.

Table 1. Cattle and buffalo population and milk production in India

Year	Population (in millions)		Milk production (million Tonnes)		
	Cattle	Buffaloes	Total	Cow	Buffaloes
1983	193.8	71.6	38.8	16.3	21.4
1986	197.9	77.2	46.1	19.5	24.7
1993	192.7	78.5	60.6	25.4	31.0
1994	193.6	79.1	64.0	25.8	32.6
1995	194.7	79.1	66.2	30.4	33.2
1996	196.0	80.1	68.6	30.8	34.8
Growth Rate in 1996/1963% (per year)	0.1	0.8	4.1	4.6	3.5

Source: FAO Selected Indicators of FAO in Asia & Pacific 1983-1993 and 1996/1963 adjusted by Malhotra, S P, 1998

Table 2. Buffalo population, milk and buffalo meat in India and the World in 1996

Item	Unit	India	China	Pakistan	World
Population	Million	82.0	22.8	20.2	152.0
Share	% age	52.7	15.0	13.0	100.0
Buffalo milk	Million tonnes	34.8	2.2	14.8	54.6
Share	% age	63.4	4.0	27.0	100.0
Buffalo meat	Million tonnes	1.2	0.4	0.5	2.7
Share	% age	44.4	14.8	18.5	100.0

Source: FAO Regional Office for Asia and Pacific Selected Indicators of Food & Agriculture (1986-1996), Bangkok

Meat Production

Trends in livestock population, slaughter rate, carcass weight and meat production in India over 2 decades (1975 to 1995) are shown in Table 3. About 5% of cattle and 10% of buffaloes are slaughtered each year. This is equivalent to about a third of the potential cattle off-take and about 2/3 of the potential off-take of buffaloes. With increasing mechanization, the demand for draught animals in the States of Punjab, Haryana, Uttar Pradesh is declining, resulting in a surplus of male buffaloes. The concept of fattening young buffaloes is largely unknown in India. However, buffalo meat processing has developed into a full-fledged business and relevant products are marketed at various stages to meet the domestic as well as the export demand.

Breeds and Performance

Murrah. This is the most important breed of domestic Indian buffalo and is distributed throughout India and several foreign countries (Ranjhan 1998). The home tract of the Murrah spreads over Haryana, Delhi, Punjab and Western Uttar Pradesh. It is a heavy animal with curled horns. Adult males may weigh between 450 and 800 kg and females between 350 and 700 kg. The milk yield varies from 1030 to 3000 kg per lactation. The average yield is between 1400 and 2000 kg per lactation of 300 days (ICAR, 1966).

Table 3. Trends in livestock population and meat production data over decade (1985-1995)

Livestock Species	Population (in millions)		Slaughter rate (%)		Carcass weight (Kg)		Meat production (in Tonnes)		Share of total production (%)	
	1985	1995	1985	1995	1985	1995	1985	1995	1985	1995
Cattle	182.4 (1.3)	194.6 (6.7)	6.1 (24.5)	6.4 (4.5)	80 (-2.4)	103 (28.0)	890 (111.3)	1292 (761.3)	34.0	31.2
Buffalo	64.5 (6.1)	79.5 (23.3)	11.0 (10.1)	11.0 (-)	138 (-2.7)	138 (-)	980 (29.9)	1204 (692.1)	37.5	29.1
Sheep	41.3 (3.0)	45.0 (9.0)	35.8 (12.4)	31.3 (12.6)	9 (-)	12 (33.3)	141 (15.4)	173 (28.1)	5.4	4.2
Goat	81.5 (16.9)	119.4 (46.5)	2.9 (1.0)	39.7 (-6.5)	9 (-)	10 (11.1)	358 (17.1)	474 (50.5)	13.7	11.4
Pigs	8.8 (26.4)	11.9 (35.2)	30.0 (17.0)	35.3 (17.7)	32 (3.1)	35 (9.4)	85 (17.1)	420 (50.5)	3.2	10.1
Poultry	161.0 (14.2)	610.0 (378.9)	-	-	-	-	161 (59.4)	578 (259.0)	6.2	14.0
	539.5 (8.2)	1060.4 (96.6)					2615 (36.5)	4141 (315.9))	100.0	100.0

Nili-Ravi: In the year 1960, the two separate breeds of Nili and Ravi were described as one Nili-Ravi breed. It is the main buffalo of Pakistan. In India, it is found in Ferozepur District of Punjab, and adjoining districts. It is a heavy breed and the colour of the skin is black with white markings on forehead, face, muzzle, legs and switch are seen commonly. The average body weight of the adult is 600 kg and produces about 2500 kg of milk in one lactation of 300 days (ICAR, 1966).

Mehsana: The Mehsana District of Gujarat State and adjoining areas are the home tract of the Mehsana breed. They are widely distributed in Gujarat and parts of Maharashtra State. The Mehsana buffalo is one of the main milk sources for various dairies operating in Gujarat and Maharashtra State. This breed has resulted from inter-breeding of Surti and Murrah breeds and has characteristics of both breeds. It is a medium sized animal weighing 350-550 kg. The horns are curved and sickle shaped. The milk yield varies from 1300 to 1800 kg in a lactation of 300 days.

Surti: The home tract of Surti buffalo lies in Kaira and Vadodra Districts of Gujarat State. It is the main animal around the area where the large co-operative dairy, Kaira District Co-operative Milk Producer Union Ltd. is functioning and developing rapidly. The Surti buffalo is a medium sized animal varying from black to brown in colour. Many animals of this breed have two white chevrons, one just around the jowl from ear to ear, and the other just on the brisket, like swamp buffaloes. The average milk yield varies from 990 to 1730 kg in a lactation of 300 days. The milk is rich in butter fat ranging from 7 – 8 per cent.

Zaffarabadi: The breed is found in the Gir forest of Gujarat State around Zaffarabad town. They are strong, massive animals with prominent convex forehead and heavy, broad, corrugated and drooping long horns curved upward at the tip in a characteristic fashion specific to the breed. Ears are large and drooping. The average weight of adult bulls is 590 kg and adult female is 454 kg.

Bhadawari: The animals are distributed in Agra, Etawah and Jhansi Districts of Uttar Pradesh. They are light to medium sized buffaloes and the yield varies from 470 to 2070 kg of milk with an average butter fat content of between 8 to 13% in a period of 300 days.

Tarai: It is found in Tanakpuri-Ramnagar, U.P. The milk yield is between 1000 and 1200 kg in a period of 300 days.

Nagpuri: It is a light breed found in Nagpur, with a body weight of 350 kg. The milk yield is around 1050 kg per lactation.

Pandharpzai: It is found in south Maharashtra, and parts of Andhra Pradesh and Karnataka. It is a medium sized animal producing about 1200 kg of milk.

Kalahandi: The breed is found in Andhra Pradesh and Orissa. It is gray in colour, and produces around 1200 kg of milk per lactation.

Manda/Ganjam: It is found in Andhra Pradesh and Orissa. It is a medium sized breed producing around 800 to 1000 kg of milk.

Sambalpuri: It is found in Orissa and is a medium sized breed.

Toda: The breed is found in Nilgiri Hills in Tamil Nadu and is a large sized animal producing about 1400 to 1500 kg of milk.

There are also breeds of Sikkimese, Assamese and South Kanara in the Sikkim, Assam and Mangalore regions.

Importance of Production Systems

In India, the predominant buffalo production system is the traditional small scale system involving small numbers of animals (2 to 5 buffaloes), that are raised by small holders primarily for milk production, and secondarily for meat production. When buffaloes are old and become uneconomical due to reproductive disorders etc., they are slaughtered for meat. A very small number (about 7%) is used also for draught. There are no feed lot management systems, especially for raising of buffaloes for meat production, unlike in Egypt. Females are used for breeding and milk production and males are used for meat/draught.

Constraints

Low Productivity: In India, about 80% of the buffaloes are of the nondescript type and consequently, milk and meat production are very low.

Seasonal Breeder: Although buffaloes breed all the year round, in practice they are generally seasonal breeders, depending upon the ambient temperature and availability of feeding resources. Silent heat during summer is very common.

Quality of Milk and Meat: One of the greatest weakness of Indian dairy industry is the quality of the meat. The basic reasons are lack of hygiene and sanitation at the production level. Furthermore, adulterants and neutralizers are also used to increase the shelf life of the milk. Buffaloes are not specially reared for meat production. Consequently, the meat is not very juicy and tender.

Research and Development

The evaluation and conservation of indigenous breeds: The importance of conservation of the important buffalo breeds, namely, Bhadawari, Surti and Jaffarabadi which show a decline in numbers due to crossing with Murrah, has to be emphasized. Breed-wise generation of data needs to be undertaken for developing a meaningful breed improvement programme.

Progeny testing- Progeny testing of bulls of the dairy buffalo, namely, Murrah, has to be further strengthened.

Feed lot for buffaloes A package of practices needs to be developed to utilise male buffalo calves for meat production. R and D efforts should be directed towards evolving cheap economic rations for meat production.

Reproduction and artificial insemination: The conception rate of buffaloes through artificial insemination (AI), is low when compared to cattle. This coupled with the problem of silent heat during summer period and longer inter calving periods, requires special R and D efforts on the part of reproductive physiologists to tackle these problems.

Genetic improvement by using MOET in progeny testing: The expected genetic gains in milk production using MOET in addition to progeny testing, gives better results. R & D focus in this direction has been initiated at a few research stations in India.

Future Strategies

Small scale buffalo farming is likely to continue in India for about another half a century. Agriculture mechanization and adoption of new technologies will continue. The major portion of milk will come from buffaloes as more and more farmers in North India are shifting towards buffalo production. Consequently, the share of buffalo meat production will also increase. The quality of buffalo meat is considered good since it is lean and fat and cholesterol levels are lower

than those of beef from cattle. It is expected that the buffalo meat will gain more popularity and a few feed lots may also be established,

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BUFFALO PRODUCTION IN MALAYSIA

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The domesticated buffalo (*Bubalus bubalis*) in Malaysia is represented mostly by the swamp type. Despite the importance of the buffalo in rice cultivation, there has been a steady decline (about 12%) in the population in Malaysia over the past 50 years. However, the current research and development (R&D) efforts are considered inadequate to prevent a continuous slide in the population, let alone reverse the trend. There is certainly a need to consolidate ongoing research activities and at the same time expand into new important areas. This paper presents the status of buffalo production in Malaysia and highlights the efforts made to exploit the full potential of buffaloes for meat.

Importance of the buffalo in the national economy

For many centuries, the buffalo has played an important role in the overall growth of the Malaysian agricultural industry. The buffalo provided draught power for the cultivation of rice. During the past few decades, Malaysia experienced a rapid increase in human population leading to an upsurge in the demand-driven consumption of livestock products. While the poultry and pig industries responded to this demand, the ruminant sector suffered severe constraints on the production systems. As a result the cattle and buffalo industry lost a major share of the market to imported beef and dairy products.

Buffalo population and types

The domestic water buffalo, commonly found in this country, has been classified into river and swamp types. In 1998, the total population of buffaloes in Malaysia was about 170,000. They were concentrated mostly in the rice growing states of Kelantan, Terengganu, Kedah and Pahang in West Malaysia (60%). The swamp buffalo is used for ploughing, harrowing and puddling rice fields. At the end of its working life, the swamp buffalo is slaughtered, accounting for about 16 percent of current meat supply. The population of river buffaloes is less than 2000 head of Murrah buffaloes brought by Indian immigrants at the beginning of the 20th century.

During the past two decades, there has been an alarming decline in the buffalo population in Malaysia with an average rate of population decline of 1.2% per year. This decline had been attributed to displacement of the buffalo with machinery for draught power in the rice fields, low multiplication rate and high extraction rate. Most farmers in rice growing areas discontinued rearing of buffaloes due not only to labour shortage, but also to limited availability of grazing land.

Production systems

Buffaloes in Malaysia are raised under two types of production systems depending upon the producer, the availability of feed and market opportunities. These systems can be broadly classified into the traditional smallholder or village system and the more recent improved system. The smallholder system accounts for over 95% of buffaloes. It is based on an integrated crop-livestock system where farmers maintain 5 to 10 buffaloes in less than 2 ha of land. Buffaloes graze during the day in communal grazing grounds or in rice fields after harvesting of rice. Breeding often occurs in the communal grazing grounds. The improved production system is

practised in two institutional farms at the Agriculture University (UPM) and the Malaysian Agricultural Research and Development Institute (MARDI). Animals are managed in established pastures for research on beef production.

In Malaysia, the contribution of the buffalo in terms of draught power is secondary to beef or milk production. Less than 1% of the buffalo population is used for draught. Prior to the introduction of the double cropping system in major rice growing areas in Peninsular Malaysia, buffaloes were used extensively for draught power and in land preparation. Since the early seventies as more and more machinery were introduced into the rice planting operations, buffaloes have been displaced.

The potential of buffaloes for draught power in the oil palm plantations appears to be promising. Since the early 1980's buffaloes have been introduced in oil palm estates to haul oil palm fresh fruit bunches (FFB) from the field to the main collection centres. Castrated swamp buffaloes, 1.5 to 2 years old and weighing approximately 200 kg, were trained for work in the oil palm plantations. The buffalo increases the efficiency of harvesting FFB in terrains where the use of machinery is both difficult and uneconomical. Using carts powered by a buffalo, a worker could increase his work efficiency by 2 to 3 folds and thereby increase his earning capacity. On a normal working day, a buffalo hauls about 4 to 5 cartloads of FFB, which is equivalent to 2.0 to 2.5 tons of harvest as compared to 1.5 tons if collected by a manual cane basket system. Buffaloes are worked for 5 to 10 hours daily depending on the needs of the farmer. The buffalo's working life spans from about 4 to 12 years of age.

Rearing of buffaloes for milk production is not prevalent among the majority of buffalo producers. Dairy buffaloes are found mainly in farms close to major cities where ready markets for milk are easily accessible. Herds of 5 to 25 animals, mostly owned by Indian farmers, are stray grazed and fed home made concentrate rations. Milk yields from the river breeds are also low compared to crossbred cattle.

Constraints and research priorities

Nutrition

The feed resource for buffaloes is mainly rice straw. Rice straw can supply a substantial part of the maintenance requirements of buffaloes, but their ability to meet production requirements is limited.

Poor digestibility and limited intake of the forages and feeds normally consumed by buffaloes and the low availability of dietary nitrogen are major limitations to buffalo production. In smallholder systems, buffaloes are grazed during the day and confined at night and fed only rice straw and sometimes a small amount of concentrates, usually rice bran and/or coconut meal. The overall effect is that the level of energy and protein intake remains low.

Deficiencies of minerals (particularly P, Na and Cu) have been identified in a number of locations in West and East Malaysia. Also swamp buffaloes working as draught animals in oil palm plantations suffer from metabolic diseases, which are related to mineral deficiencies which affect the balance of minerals in the diet.

Reproduction

Most buffaloes, particularly the swamp type, produce two calves every three years. Under field situations, due to biological limitations as well as the seasonality of feed supply, it is not possible for a buffalo to calve and then conceive immediately during the next few months when feed is still abundant. Thus breeding is delayed until the next year. Also most male buffaloes are castrated for draught purposes restricting opportunities for mating.

Diseases

In general, buffaloes are more resistant to diseases than cattle. In most countries, *Neoscaris vitulorum* and *Fasciola spp* are major parasites inflicting heavy mortality in the buffalo, but in Malaysia, the most pathogenic parasites are coccidia and strongyles, which cause enteritis and gastro-enteritis in buffalo calves below three months of age.

Research and Development

Recognising the importance of the buffalo in agriculture, both the Agriculture University (UPM) and the Malaysian Agricultural Research and Development Institute (MARDI) established research farms in the early 1970's to study the potential of the swamp buffalo as a meat producer.

Research achievements covering aspects of birth weight, growth rate, reproduction nutrition and feed resources utilization, rumen manipulation, meat quality, breeding and genetic improvement are reviewed.

Birth weight and growth rate

The mean birth weight of swamp buffalo calves at MARDI Research Station were 31.2 kg for male and 31.0 kg for female while the average weight of fully grown adult male and female is about 450 kg and 390 kg respectively. The mean daily gain of 12 to 18 month old buffaloes on improved pasture was 0.42 kg. Two year-old draught buffaloes grazing only the native pasture available in oil palm plantations produced daily gains of 0.55 kg. Only limited work has been reported on the performance of fattening swamp buffaloes in feedlot. Swamp buffaloes fed 50.5% palm kernel cake (PKC), 15% palm press fibre (PPF), 30% palm oil mill effluent (POME), 1% urea and 3.5% mineral-vitamin premix produced an average daily gain of 0.58 kg/day.

Reproduction

In the UPM buffalo herd, there has been several advances made in the field of reproduction. Hormone assays have been used to study the reproductive physiology and reproductive problems such as failure to restore the oestrous cycle following calving (postpartum anoestrus), which is one of the major causes for the long calving intervals. Both suckling and nutrition influence the calving to conception intervals. The phenomenon of "silent oestrus", once believed to be a major problem, can be overcome by improving oestrus detection techniques.

The female buffalo is polyoestrous. The oestrous cycle is 21 days and oestrus lasts 18 to 21 hours. Overt signs of oestrus are less obvious than in cattle. Oestrus commences during late evening with peak sexual activity occurring at night. Although matings do occur during the day, the intensity of sexual activity is usually depressed. For oestrous detection buffaloes are penned and tested daily between 2000 h and 2200 h using a vasectomised buffalo fitted a marking device. In the swamp type, puberty occurs at about 24 to 36 months age, the age at first calving is 39 to 56 months and the mean calving interval is about 532 days. The gestation length of the swamp type is about 330 days. Swamp buffaloes have been artificially inseminated with frozen semen of the river buffalo. The hybrids are heavier, with higher growth rate and fertile. Studies at the MARDI Research Station, Bukit Ridan, have shown that breeding of buffaloes under intensive systems generates a higher calf crop than in the extensive system.

Artificial insemination (AI) in the buffalo has not been practised in Malaysia due to poor oestrus detection techniques. Despite the availability of frozen semen and fixed time insemination technique, there has been no progress in AI.

Feed resources

Several studies have been conducted to improve the digestibility and nutritive value of fibrous crop residues through physical and chemical methods. However, only in a limited number of project locations has the effort been made to transfer this technology to small farms.

Increased production from buffalo on straw diets can be achieved by spraying the straw with urea to increase the efficiency of straw fermentation in the rumen. This established technology has, however, not been generally applied at the village level. Urea treatment of straw has now been replaced by enhancing the utilisation of straw with small amounts of both soluble and by-pass energy and protein. The soluble energy and protein in the diet as molasses and urea will stimulate the microbial activity of the rumen due to increased straw intake. The by-pass component of the diet is cotton seed meal or high quality forages such as *Leucaena* or cassava leaves.

A recent innovation to facilitate maximal utilisation of least cost basal diets is the development of gelled molasses/urea lick or block. The use of solidified feed blocks containing molasses, rice pollard (or bran), minerals and a high concentration of urea have undergone preliminary testing as a means of correcting fermentable N deficiency in the river and swamp buffalo. Since blocks can be fortified with both macro- and microelements and other potentially essential nutrients for rumen microbes and the animal, they may also be considered for correcting multi-nutritional deficiencies.

Formulations for the fattening of buffalo calves using local feedstuffs, such as oil palm and rice by-products, have been made to obtain high average daily weight gain. Swamp buffaloes raised on feedlot using oil palm by-products as major feed ingredients can reach a normal growth rate of about 0.59 kg per day and age at puberty was significantly lower in bulls on intensive (21.5 months) than in bulls on free grazing (28 months) systems.

Conclusions

Double cropping, mechanisation and replacement of buffalo power in rice farming have drastically affected the traditional system of buffalo rearing in Malaysia. A concerted effort must be made to arrest the decline in the buffalo population and promote buffalo draught power in oil palm plantations and meat production.

The prospects for beef production from buffaloes managed in oil palm plantations and fed palm oil milling by-products are indeed very good. Large-scale feedlots could be established in oil palm estates. Buffaloes for these feedlots could be raised within the oil palm plantations. Breeding herds need no additional grazing land other than the land under palm while supplementation is limited to providing mineral licks. The reproductive performance in such herds is superior to those in the institutional herds maintained on established pastures. A herd of 100 breeding females could provide about 50 weaners for fattening each year. If growth rates of calves are increased through crossbreeding with the river type of buffaloes, average daily gains of about 0.7 kg could be expected.

Research and Development agencies should focus on improving the productivity of the buffalo, which has adapted admirably to the Malaysian environment. The swamp buffalo could then fulfil its role as a meat producer more effectively and also provide the draught power to the oil palm industry.

CARABAO INDUSTRY SITUATION IN THE PHILIPPINES

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Introduction

In the Philippines, the carabao, a swamp type buffalo (*Bubalus bubalis* Linn., 2n=48) plays a major role in the traditional farming systems. Millions of farmers rely on this animal for draft power for almost all farming operations such as land preparation, hauling, pack animals and other tasks. The carabao also provides the farmer with income from the sale of milk and live animals for slaughter. The hides are used in the leather industry and at least 70 tanneries benefit from skins and other by-products (hooves and horns). The estimated value of production in 1998 was 12.1 billion pesos of which 8.1 billion pesos is in the form of draft, 3.5 billion pesos is in the form of meat and the rest is the form of milk and hide.

Undoubtedly, this huge animal resource will continue to play this role for many years to come, as there has been a dramatic increase of land ownership below 1.0 ha and a corresponding decline in land ownership above 2.0 ha in the last decade. This development ensues as the land available for cultivation continuously declines as a result of the increase in urban usage, as against the relative increase in the number of people in the rural villages. Under such a scenario, the only logical consequence is to intensify crop-livestock integration, maximize the utilization of the available biomass for production of food to increase income. The water buffalo is perceived to play a very significant role in such sustainable crop-livestock integrated systems by providing draft power while at the same time converting fibrous plant materials that is not suitable for human consumption into protein rich food.

Notwithstanding the potential role of the buffalo in the crop livestock system, there is also an increasing transformation particularly in integrated rice-producing areas, where the carabao is increasingly being replaced by the small hand-tractor as source of farm power. Under such development, the carabaos can be harnessed as potential source of meat and milk.

Population Trend, Growth Rate and Slaughter Rate

The carabao population in 1999 was 3.01 million, 99% of which is found in smallholder farms, the sector that constitutes the overwhelming majority of the country's agriculture, while the rest are raised in commercial farms. This important animal has been of use primarily as a source of draft power and meat. From 1991 to 1994, there was a decline in the population at an average rate of 3.58% per year. This has been the result of an imbalance between the high extraction rate and the slow reproductive rate. From 1995 to 1999, the carabao population changed positively from 2.71 to 3.01 million or at an average rate of 3.6%. The increase in the population may be attributed to importation of buffalo meat, which started in 1993. This resulted in the reduction in extraction rate from the domestic population (Table 1).

An average of 220,423 heads of carabaos were slaughtered yearly from 1992 to 1999, at an average yearly extraction rate of 7.96% of the population (Table 1). The slaughter rate which has been increasing during the period 1991 to 1994, showed the lowest value in 1995, while it gradually increased by 5.5% from 1996 to 1999. The positive growth in carabao population started in 1995 when the slaughter rate was lowest and carabeef importation assumed a major share of the beef industry. In 1999, the number of buffaloes slaughtered rose again to 8.45% of the total carabao population.

Table 1 Total carabao population; total slaughter and carabeef importation (1992-1999)

Item	1992	1993*	1994	1995	1996	1997	1998	1999
Total carabao population (M head)	2.58	2.57	2.55	2.71	2.84	2.98	3.01	3.01
Total slaughter (300 head)	211.6	218.4	225.8	196.6	208.43	225.52	225.79	254.25
Carabeef Importation	No imports							
Quantity ('000Mt)		0.436	0.946	17.21	21.80	21.80	21.38	34.43
Value (M Pesos)		12.6	272.5	519.9	719.4	719.4	1,017	

*Year PCC was established

Source: BAS, NSO and NMIC

Analysis of Industry Gaps

Growing gap between supply and demand

From 1980 to 1994, the carabao sub-sector experienced a significant decline in population at an average rate of 1.9% per year. However, an increased of 3.6% was achieved from 1995 to 1999 (Table 1). In many respects, the decline in population reflects a reduced potential of the subsector to produce, be it in the form of farm power, meat and milk, a summary analysis of current and future patterns of supply and demand is presented below.

Demand for meat vs. supply

The average annual production of beef and carabeef during the last five years (1992-1996) was 197.9 and 105.7 ('000 MT), respectively. This supply is continuously being provided mainly by local production. Between 1991 to 1996, importation began to contribute a major share to the beef supply situation. Imports, which accounted for only 9% share of the beef supply in 1991 rose to 22.36% in 1996. There was a more dramatic increase of carabeef, which saw importation of buffalo meat rise by 7,796% from 1993 to 1999 (Table 1). The increase in imports is a reflection of the increase in demand and perhaps an increasing capability of the consumer to purchase. The effect of these importations in the short and medium term has been reflected in an increase in population of both sectors (27.5% for cattle, from 1.63 million 1990 to 2.25 million 1997 and 16% for carabao from 1993 to 1997).

Over a 15 year period, (1980-1995), the overall meat consumption by Filipinos grew by 41%. Beef/carabeef consumption grew much faster (72%) than other meat products except for chevon during the same period. With increasing population and the expected increase in buying capacity as a result of an improvement in the economy, meat consumption is likely to increase even more in the future. This implies that there will be an even bigger market for beef/carabeef. Meanwhile, the continuing influx of low/cost beef/carabeef products, particularly manufacturing grade beef, may create a dent in the price structure of these products in the domestic market in the future. The long term effects and extent of this impossible implication must be assessed and appropriate actions/recommendations be made.

Demand vs. supply for draft power

The rate of substitution of carabaos with small hand tractors in selected irrigated rice-producing areas is about 35% during the last few years (Table 2). This could have been brought about by the increase in wages in the agriculture sector and the benefits brought about by mechanization of farm activities. The pattern however, is not seen in selected rainfed and upland/hilly areas where carabaos remain as the major source of farm power. In recent years, the increased demand for

labour outside agriculture and changes in land use pattern brought about by industrialization have considerably altered the agricultural landscape. Ownership of land at 1 ha and below increased by about 70% between 1980 and 1991, while those for land areas larger than 1 ha changed negatively (Figure 1). This trend only manifests the expected reduction in size of land ownership, due to decreasing area of agricultural land and a corresponding increase in relative number of people working in the farm in the last several years.

Table 3. Carabao substitution by small hand tractors for farm activities

Agroclimatic zone	Estimated replacement %
Irrigated land	15 – 35
Rainfed land	3 – 5
Hilly land	0

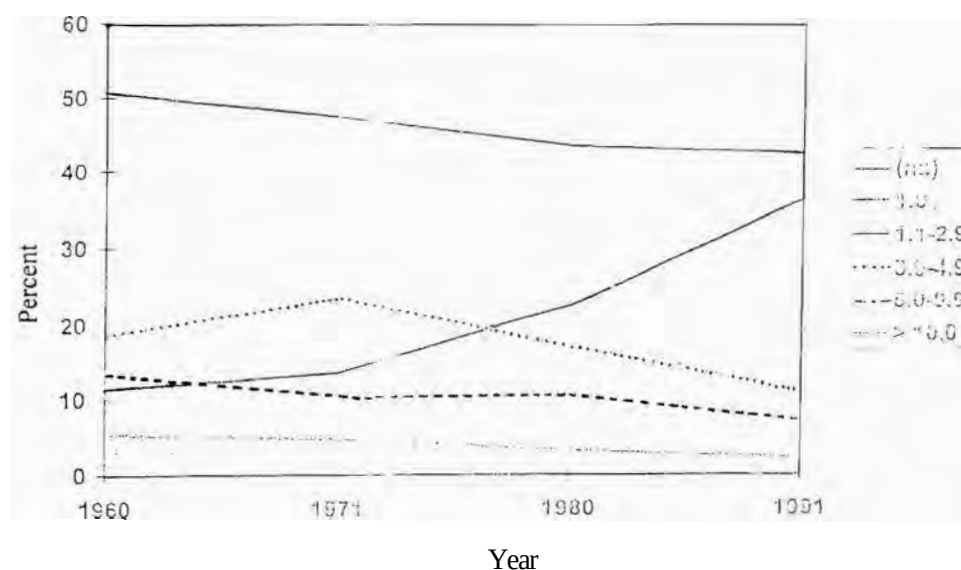


Fig. 1. Percentage distribution by land size in Philippines (1960 – 1991)

It follows therefore that intensification of farming will have to take place in the coming years as available land area per farmer becomes smaller. Usage of farm machinery may be effected by economies of scale and the perceived increases in cost of oil and spare parts of farm machinery. Thus, it becomes clear and logical that crop-livestock integration is the system of choice if a more sustainable production is to take place in the coming years. Buffalo as a source of draught power and organic fertilizer as well as a converter of farm residues that normally are not suitable for human consumption would be an indispensable component of the future sustainable crop-livestock farming systems. The extent and continuing role of this important animal as a source of draft power has to be assessed in the light of this changing agricultural economic landscape.

Demand vs. supply of milk

The increasing human population and fast urbanization, coupled with increasing per capita income, are indicators of the potential increase in demand for fresh milk and milk by-products. The need for additional sources of nutritious food is also dictated by the high rate of malnutrition among children,

The growing demand for milk and dairy products is reflected in importation which registered an increase of 19% and 23.91% in 1994 and 1995, respectively, as domestic production (historical average of 17.04 million liters, 1989-1993) still remains below 1% of the total requirement (Table 3). It is expected that the gap between local milk production and actual demand will widen in the future unless a suitable mechanism is installed. With sustained efforts to produce potential milking carabaos via a massive introduction of dairy buffalo germplasm, the potential contribution of milk and related products from the buffalo sector is expected to increase a few years from now. The gamut of forces required to realize this expectation need to be fully understood and installed.

Table 3. Milk consumption and importation (1992-1998)

Item	1992	1993	1994	1995	1996	1997	1998
Total consumption (million/kg/yr)	1,024	1,056	1,072	1,088	1,120	1,152	1,168
Local production (million/kg/yr)	13.43	12.50	2.12	12.11	11.50	10.22	9.24
Importation							
Volume (LME M/kg)	1,102	1,089	1,296	1,606	1,379	1,671	1,392
Value (million US \$)	264.7	270.9	330	438.11	405.02	444.10	312.92

Source: National Dairy Authority

Factors Affecting the Productivity of Carabao

Technical, social, economic and policy factors influence the productivity of the carabao sub-sector, just like in any biological system. Below is a summary presentation of the main constraints to local carabao production.

Production/technical constraints

Biological characteristics of carabaos

Water buffaloes have an inherently longer gestation period than any other domestic farm ruminant. The average gestation length is 310 to 315 days. Given a postpartum service period of 60 to 90 days, production of one calf per year is unlikely to be achieved even under the best conditions. This characteristic would have a major effect on the measure of the overall reproduction efficiency over a given period.

The Philippine carabao is essentially a swamp-type buffalo and is recognized as a draft animal. It has the potential for meat production but has low genetic potential for milk production. The genetic potential for growth and milk production can be improved through the introduction of dairy buffalo germplasm, long demonstrated to be possible. The inherent long gestation period, longer set-back period and late period of reproductive maturity render the production of highly upgraded buffaloes through continuous backcrossing a relatively long process. In essence, it will take about 15 to 20 years or 4 to 5 generations of backcrossing to get an animal that would express milk production close to purebred dairy buffalo.

It appears that the most practical approach to carabao-based enterprise development is to develop a significant number of highly productive buffaloes through sustained upgrading and infusion of germplasm from elite sires. However, infusion of low-cost, highly productive dairy buffaloes from the other continent so that the envisaged specialised milk production from buffaloes would take place is risky due to the possibility of introduction of exotic diseases from the country of animal origin. Acquisition of highly productive dairy buffaloes from other sources is hampered by the inherently high cost of importation. Under such conditions, the only option possible is to acquire semen from elite sires. Another possibility is to source embryos from other countries,

which may be realised, as techniques of superovulation and *IVM/IVF* in buffaloes are fully refined to acceptable efficiencies.

Socio-economic constraints

Raising carabaos in the villages has been largely associated with crop-dominant farming systems. Under this scenario, the carabao is regarded as a source of draft power and secondarily, as a source of income. This farmer's perspective has a major impact on the management and overall development of carabaos in the villages, Crops, being the dominant source of cash, take the premium attention as well as investment. The willingness of farmers to put in a cash outlay to procure inputs such as fertilisers and insecticides is associated with the expected gain to be in their hands in short span of one cropping season. In fact, the carabao is considered the input in this cropping system.

Farmers whose stocks are kept primarily for draft, do not appreciate much, the benefits that they can derive from improved reproduction and production. In fact, the substitution of carabaos with small hand tractor for farm work is increasing, particularly in intensively cultivated, irrigated areas. Farmers whose main purpose of keeping carabaos is for draft find it more convenient to maintain their hand tractors, where possible, than to take care of draft animal throughout the year. This is particularly true in areas where seasonality in cropping and farm activities are seen, e.g. rice areas, as period of field work when animals are actively used is shorter than the time the work animal is at rest. Farmers find it as an extreme burden to maintain carabaos over this long rest period just to have the animals ready for the next short working season. However, in areas where farmers get substantial cash income in the form of daily sales of milk, institution of improved husbandry is readily seen. This has been increasing in areas where farmers have animals with higher capability to produce milk.

The constraints associated with the slow rate of technology adoption can be partly assessed by taking cues from the above discussion. At the industrial level, the option to raise carabaos primarily as source of income is largely influenced by relative profitability. Compared to cattle, in general, carabaos are priced much lower as source of meat. This pattern emanates from the fact that a larger percentage of carabaos sent to the meat market are old and retired draft animals. Under this condition, farmers who raise and sell carabaos at younger age for meat are therefore penalised. This pricing structure can be expected to persist for some time. Considering that a larger proportion of locally produced carabao meat goes to processors, availability of low-cost imported buffaloes meat through importation, the extent to which this recent development can influence local buffalo meat production is yet to be determined.

Development of carabaos as source of milk for household and community consumption appears feasible. But the challenge lies on the ability to stimulate local production of milk at a level that would significantly contribute to the total milk supply. This challenge is formidable as competition of low-cost milk from importation exists. The challenge is how to make the local production system competitive.

Policy constraints

Important liberalisation

The immediate affect of import liberalisation on the carabao sector, particularly on buffalo meat can be readily seen in the significant reduction in the relative number of carabaos slaughtered in the past two years, a period when a surge in the influx of imported buffalo was recorded. From the biological point of view, this is beneficial as it increases in the number of the local breeding base. The extent to which this affect will be beneficial to the overall sector requires serious attention.

As foreign products flood the domestic market, there is a need to take a closer look on how to make the local production and postproduction system more competitive. Pricing mechanisms and market structures for carabao products have to be improved.

For milk, problems including adulteration, deterioration of milk quality and spoilage during transport should be seriously addressed. Of prime need is a policy that will allow sure, ready and a sustainable market for liquid milk. Institutionalisation of the national milk-feeding program for grade school students is a logical approach. In like manner, there is a need for a policy that will support the milk producers (especially the village-based or smallholder dairy farms: to efficiently store, process, package and transport either fresh milk or processed milk products. Basic market infrastructure and support facilities must be put in place.

Credit policy

One major constraint to production, particularly on building up an enterprise, is capital. For years, many lending institutions have created windows for small scale farmers, yet the affect and impact of these available credit windows on the overall industry has not been significant. One major area that requires attention is the relatively high interest rate and procedural requirements for credit availment. Livestock production, particularly those involving large ruminants, takes a longer lag time. Because of this, the profitability of the overall operations is jeopardised by accumulation of payments from high interests. Perhaps a specialised credit window that would stimulate small-scale farmers to access credit to raise large ruminants is very essential.

The Carabao Development Programme

The carabao development programme (CDP) of the Philippine Carabao Center, officially launched by President Ramos in 1993, is premised on the need to improve the genetic potential of the carabao for better and more efficient production of meat, milk, draft and hide. These efforts are aimed at stabilizing the carabao population with a corresponding increase in genetic qualities and are directed towards the development of competitive carabao-based or carabao-related enterprises. Such development is primed at increasing income, improving nutrition and general well being, of the millions of rural farming families. The CDP, therefore, is a very important socio-economic program that addresses the national concerns on poverty alleviation, nutritional improvement, income distribution and people empowerment. The main program components are described below:

Establishment of the gene pool

This sub-program is aimed at conserving the best germplasm both of the native swamp buffalo and purebred riverine types. In effect, a genepool of the best native carabaos and separate genepool of the best dairy breed of buffaloes is being established. This is very essential not only for the immediate requirements of the CDP but, more importantly, for the long term genetic improvement program. The main activity is sustained testing and selection of the best animals from the imported and locally available stocks. The propagation and utilization of this superior germplasm shall be complemented by the use of reproductive biotechniques.

Intensification of the national upgrading program

This program components answers the need for improving the genetic potential of the native carabao by way of introducing the dairy buffalo breed through AI as well as natural services. This involves training of technicians from the local government agencies, non-government organizations on artificial insemination and pregnancy diagnosis. A "Bull Loan Program" was initiated for the farmers to make available Purebred Murrah bulls for use in natural mating. Efforts are being intensively carried out in areas close to potential markets for milk, giving

priority to identified milk sheds. AI services are being provided by PCC extensionists, in collaboration with LGU/RFU technicians

Carabao-based enterprise development

As efforts to produce more dairy/meat carabaos are intensified, there is an expected corresponding increase in carabao based enterprises. PCC assists in this development through the provision of technical assistance, training, cooperative development, credit and assistance for market development. Two banner programs were established to facilitate the enterprise development. The "25-Cow Dairy Buffalo Module" and the "25-Heifer Dairy Module" can be availed by qualified cooperatives. This is the direction PCC is pursuing with efforts to further strengthen product development and access to markets.

Research and development

Two regional PC centers, PCC at CLSU and PCC at UPLB, led in the generation of basic information and development of technologies on carabao breeding, reproduction, nutrition and meat and milk processing. In 1999, the National Carabao R & D Program of the agency was developed. The general direction of this program is expressed in the various program components, all focused towards increasing productivity and efficiency. The program components cover the vast areas of technology, socio-economics and policy. They are the following:

Program I. Improving carabao productivity for milk and meat

This program aims to:

- a) Conserve genetic diversity among existing water buffaloes resources to meet future breeding requirements;
- b) Select on a continuing basis, highly productive animals for milk and meat for expanded usage;
- c) Utilize biotechniques to hasten genetic improvement among water buffaloes;
- d) Test performance of resulting crossbreds between swamp and riverine animals at various blood composition levels for optimum milk and meat production; and
- e) Develop feeding and management systems to enable selected animals to express their full genetic potentials.

Program II. Increasing calf crop in water buffaloes in the villages

This program will be carried out to:

- a) Improve the yield and quality of processed semen from progeny-tested sires used for wide scale AI programs;
- b) improve the success rate of the current system of AI in the villages;
- c) improve the utilization of bulls loaned out for natural mating; and
- d) Develop appropriate animal health and management systems to improve the pregnancy rate and reduce pre-weaning mortalities.

Program III. Development of buffalo-derived products

This program will be carried out to:

- a) Develop and promote technologies for processing, packaging and marketing milk and its products such as mozzarella cheese and other curd-based products.
- b) Improve processing, packaging and marketing of existing and new products from buffalo-meat; and
- c) Assist in refining and promoting technologies for other buffalo-derived products such as leather, horn, etc.

Program IV. Development of a sustainable village-based carabao improvement program

This program will be carried out to:

- a) Evaluate effectiveness and efficiency of various upgrading strategies;
- b) Develop a sustainable village-based AI system; and
- c) Evaluate the performance of AI technicians in response to specific incentives.

Program V. Socioeconomic and policy studies

This program will be carried out to:

- a) Evaluate the impact and effectiveness of existing policies affecting the carabao industry;
- b) Generate relevant and up-to-date data on carabao production, utilization and marketing in the Philippines;
- c) Analyse the demand and supply situation of carabao products and by-products in domestic and international markets; and
- d) Analyse the issues and problems affecting the implementation of the carabao development program.

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THE CURRENT STATUS OF BUFFALO PRODUCTION IN SRI LANKA

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Abstract: Buffaloes have traditionally played an important role in small farms in Sri Lanka, where they are used primarily for activities related to paddy cultivation. Although the slaughter of buffaloes, unless unfit for work, is banned, it is estimated that buffalo meat contributes up to one third of the beef production. Buffaloes are increasingly being used for milk production, particularly in the peri-urban areas, where fermented buffalo milk, in the form of curd, finds a ready market. ~~Is~~ present production level of curd from buffalo milk cannot meet the increase? consumer demand and there is a great opportunity to increase this activity.

The last National Agricultural Census was carried out in 1982 and the population figures available since then are estimates and projections. Certain trends can however, be seen. In recent times, particularly in many of the large irrigation and human settlement schemes, the use of buffaloes for farm power has declined. The large herds of buffaloes that earlier roamed the dry zone and dry intermediate zone have declined both in numbers and herd size. Together with this, there has been an increase in the proportion of upgraded dairy buffaloes. With the expansion of irrigated settlement schemes and the use of land previously used as communal grazing land are increasingly used for crop production. Extensive buffalo rearing has become extremely difficult. A considerable degree of genetic degeneration is evident, due to lack of selective breeding and since the best animals are often castrated for draught purposes. High calf mortality is another problem that can be seen in among buffaloes. These two factors, together with slaughter for meat tend to reduce the both the quality and the quantity of buffaloes in Sri Lanka. Scarcity of dairy buffaloes prevents significant expansion of buffalo dairying.

Encouraging farmers to reduce herd size and change their farming systems and move into more intensive farming of dual purpose animals is the present policy relating to buffalo development in the country. More emphasis has been given to increase the availability of upgraded dairy animals and improve their management. Equal emphasis has been given to improve processing technology of buffalo milk products. Although some animals will be available for meat, it is time to consider raising buffaloes for this purpose alone. Marginal lands often ideal for buffalo raising but not suitable for any other form of land use, can be utilised effectively for meat and milk production from buffaloes.

Introduction

The Sri Lankan economy is characterized by an increasing GDP per capita (US \$ 804 in 1998), the changing nature of food habits and an increasing demand for animal products, Rice being the staple food of the nation, paddy cultivation has received a priority attention in the food production drive. The agricultural sector's share of GDP has fallen from 28% in 1975 to 18% in 1998. However, the livestock sector share of the agricultural GDP has increased from 5.6% to 7.0% during the same period. Therefore, the livestock sector plays a useful social-economic role particularly with small holders.

As a multipurpose animal, domesticated water buffaloes play an essential role in solving the above economic problems. They convert material, such as natural forage, agricultural and agro-industrial by-products that have no role in human nutrition, into food for humans. They contribute towards the improvement of the food situation, employ more labour, increase income-generating opportunities and is acceptable to all communities, without being subject to any religious constraints. Possibilities of increasing productivity, profitability and income generating opportunities of small holder buffalo units have helped to overcome the agricultural debt cycle and build up an insurance coverage against frequent crop failures in the dry zone. It has helped to build the total capital assets or a store of wealth that can be used for any family emergency.

Over 90% of buffaloes are used mainly for activities related to paddy cultivation, over an average period of two (02) months per year. They are involved in ploughing, harrowing, treading, leveling, puddling of paddy fields and finally in threshing of harvest. They still contribute one third of farm power needs in paddy cultivation activities and is becoming increasingly important in the context of escalating prices of crude oil, tractors and associated agricultural implements. Their usefulness has become more important with expansion of paddy cultivating land areas, developed under irrigation settlement schemes. In addition to activities related to paddy cultivation, buffaloes are still used for mixing clay in the production of bricks tiles and pottery products in certain areas. Some of traditional oil-extraction machinery and agro-wells are also operated using buffalo draught power.

Although the primary use of the domesticated buffalo is still for draught, this animal is now increasingly being recognised as a potential dairy animal in many parts of the country, especially in the peri-urban areas. The currently estimated buffalo cow population is around 200 000, which produces 25% of milk in the country. A substantial proportion of the milk obtained from buffaloes is fermented into curd, a highly nutritious delicacy in Sri Lanka. In a few areas of dry and dry intermediate zones, milking of a few animals in indigenous buffalo herds is continued, as a traditional because of the belief that firmly set curd made out of milk under warm dry conditions from buffaloes, fed on more alkaline grass found around lagoons, is more delicious. Therefore there is a special niche in the market for curd produced in the southern coastal areas of the country. Since buffalo milk is rich in fat, protein, SNF and calcium content, farmers receive a relatively higher farm gate price (of Rs. 18.00 per litre) for fresh milk. Farmers however make a higher profit by selling milk as curd (at Rs. 40 per litre). The present production level of curd does not seem to be able to keep the pace with the increasing in consumer demand. This enterprise has helped curd producers to improve their quality of life, financially, nutritionally and otherwise. In broad terms, as a component of rapidly changing and expanding economy, buffalo rearing combined with value addition activities, supplies inputs to support a wide range of downstream industries. For example, a special curd marketing network has emerged in Metropolitan areas for marketing of curd using economical packaging material that can be recycled. Some of producers in peri-urban areas have also begun to produce Mozzarella cheese from buffalo milk, which is an essential ingredient in the preparation of "Pizza", a recently popularised Italian delicacy in Sri Lanka.

Slaughtering of buffaloes is banned in Sri Lanka, because of the important role they play in rice cultivation. However, their contribution to beef production in the country is around 33%. Hides of buffaloes are used for production of leather and horns in the manufacture such as combs and other ornamental items. Buffaloes are also used in traditional rituals related to paddy cultivation in some regions. Buffalo manure is an important source of organic fertiliser that is traditionally used by farmer: in the cultivation of paddy, home-gardens and other crops. Buffaloes in coconut lands assist in weed control and provide manure for improvement of productivity of coconut lands.

Population Statistics

The estimated number of buffalo owners in the country is around 100 000. However, hardly any of them are full time buffalo farmers. About 87% are crop producers, who rear buffaloes as an additional source of income. About 64% use buffaloes for draft purpose, 34% for milk and draft, while only 2% keep buffaloes purely for milk. The population of domesticated buffaloes in the country shows a declining trend. The 1.0 million buffalo population in 1987 has reduced to 0.72 million in 1998. Buffaloes are spread throughout the country, with high concentrations in certain areas due to particular farming systems, market and socio-cultural reasons. The average herd size is around 22.5 animals. However, this figure is heavily dependent on the agro-ecological zone. Larger herds with an average of 40 to 50 animals are found in rice growing areas of the dry zone and dry intermediate zone. Smaller herds with an average of 06 to 08 animals are found in mid and low country wet zones.

Breeds and their Performance

Average mature body weights and average lactation yields of indigenous pure river type breeds are 300 and 450 kilograms and 350 and 1500 litres respectively. The lactation length is about 160 days in indigenous animals and 300 days in river type breeds and their crosses. When these animals are used for draft purposes, they take 4.7 days to plough, 2.7 days to level, 13.2 days to puddle and 8.8 days to thresh the harvest from an acre of paddy land. Breed, sex and age have little influence on draught performance. All buffaloes irrespective of breed are suitable for work after three years of age.

The breeding policy of the Government is to upgrade the indigenous draft animals into dual-purpose dairy animal. The upgrading programme is supported by importation of nucleus herds and semen, maintenance of nucleus farms and bull mother farms, promotion of artificial insemination among buffaloes and the distribution of upgraded bull calves. Natural breeding is more popular among farmers. The age at first calving and calving interval of indigenous animals under present rearing systems are around 44 months and 15 months respectively, which are superior to the performance of river type breeds and their crosses.

Production Systems

Two thirds of national buffalo herd live in the dry zone and dry intermediate zone where they roamed freely under extensive management system in communal herds. They graze on natural forage available in dry reservoir beds, shrub jungles, fallow paddy fields, abandoned and uncultivated agricultural lands, road side grass and other vacant land. Buffaloes are able to utilise these marginal lands more efficiently. They usually graze during daytime and are paddocked at night. However, in certain areas such as Amparai and Batticaloa districts, they graze both during the day and night. Feeding of paddy straw is practised in certain farms. This system which is a low input low output less external input dependant farming system is highly profitable needing less labour per animal.

The semi-intensive system where animals are tethered during the day is more popular in the coconut triangle, mid country and low country wet zones. The feed is supplemented with banana stems, jak fruits and certain other agricultural and agro-industrial by-products. In the low country wet zone new dairy buffalo systems have taken advantage of forage available in the large tracts of marshy and water logged wetlands. Very intensive buffalo farming systems exist in peri-urban areas, utilising commercial concentrate feeds to support high levels of production.

Constraints

With the expansion of irrigable land area brought under human settlement schemes, in dry zones and dry intermediate zones and the alienation of traditional communal grazing lands for crop production, extensive buffalo rearing has become extremely difficult and uneconomical to maintain. Buffaloes are being displaced due to the depletion in the extent of the traditional forage base. However, farmers do not fully utilise other available local feed resources for many reasons.

Most of the buffaloes are used for draft purposes only for a maximum period of two months a year. Farmers therefore do not receive any meaningful benefit from them during rest of the year. Consequently, buffaloes tend to be neglected by farmers. There is general indifference towards the breeding, feeding, management and health care of these animals. However, where animals are used for milk production, a difference in their attitude towards buffaloes is evident.

A considerable degree of genetic degradation has been observed due to the lack of selective breeding and deficiencies in production occur partly due to this neglect. Artificial insemination (A.I.) for buffaloes had been introduced many years ago. However, it is not popular because of

problems in detection of heat signs of cycling animals. There is a shortage of skilled manpower for implementation of the buffalo A.I. program.

High calf mortality rate (>25%) is evident among buffaloes. Calf diarrhoea, worm infestations and infectious diseases are the most common conditions associated with these deaths. Poor calf management, inadequate calf salvaging and health care programs are responsible for this situation.

Scarcity of dairy buffaloes hinders the expansion of the buffalo dairy Industry. Most fanners produce buffalo curd under very poor hygienic conditions. As a result the quality of these products has become questionable and unsatisfactory. Many pathogenic microbes such as *E. coli*, *Staphylococcus aureus*, fungi and mould species have been found to be present in many curd samples obtained from the market, at levels above the safety standards.

Most Sri Lankan paddy farmers seem to adopt the same traditional farming practices used by their ancestors, in the use of draft animals and implements in land preparation. Very little scientific effort has been made to study this traditional system and implements, and develop techniques with a view to improve the efficiency of the system.

Restricted cattle movements and conflicts between crop farmers and buffalo owners have continued over a long period of time. Trespassing by buffaloes into agricultural lands and associated crop damages frequently cause severe social problems.

The restrictions on transport of molasses and its misuse by farmers has impeded the popularisation of the use of molasses in the production of low cost urea, molasses and mineral supplementary feeds in feeding of buffaloes.

Many organisations are involved in development of buffaloes in this country. They do research, supply necessary inputs and services, formulate and implement policies, strategies and development plans. However, understanding, interaction and co-ordination among these organisations is still weak.

Plenty of resources including manpower, funds and materials are available both at farmer and institutional levels. However, these resources are underutilised and poorly managed. As a result, the achievement of the goals in buffalo development have been delayed.

Research and Development

Until the 1980's, very little scientific research had been done on buffaloes in Sri Lanka. However, after a workshop held in 1980 by the Swedish Agency for Research Co-operation with Developing Countries (SAREC) on this subject, there has been an exponential increase in research publications. More detailed information on these publications are available in the bibliography published in 1994 and the compendium of research information published in 1999 by the National Science foundation.

Encouraging farmers to reduce herd size and change their farming systems to more intensive dual purpose systems is the present policy of buffalo development in Sri Lanka. More emphasis has been given to increase the availability of upgraded dairy animals and improvement of the management practices. Equal emphasis has been given to improve the processing technology of buffalo milk products. Accordingly, new development programs such as development of peri-urban buffalo dairies and introduction of new farming systems such as the Smallholder Intensively Managed Buffalo units (SIMBU) can be seen in the country. A national buffalo information centre has been established by the SAREC/NARESA buffalo research and development programme and a monograph on Sri Lankan buffalo, a training manuals for

extension workers and information leaflets for farmers have already been published by this programme for development of buffaloes in Sri Lanka.

Eminent scientists in Sri Lanka have conducted intense research studies on different aspects of buffalo production. They have mainly focussed their studies on health, nutrition and physiology, reproduction and breeding and management and utilisation. On the basis of the research findings, a package of management practices have been introduced. This package which includes, vaccination schedules against diseases such as Haemorrhagic septicaemia, a treatment schedule against *Toxocara vitulorum* and calf diarrhoea, methods of feeding crop by products and agro-industrial wastes, planned breeding programmes and low cost housing systems has been introduced to buffalo farmers specially during last two decades.

THE CURRENT STATUS OF BUFFALO PRODUCTION IN THAILAND

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Abstract: Thailand had the second largest number of swamp buffaloes in the world in the past. However this buffalo population had drastically declined from 4.7 million in 1990 to 1.9 million in 1998. Approximately 83% of the Thailand's buffaloes live in the Northeast where most agricultural production is under rainfed conditions. Thai buffaloes are of the swamp type genetically. The majority (90-95 %) are grey to black in colour, while the rest are white. Most of the buffaloes are raised by small farmers in the rural areas.

The present declining trend in the buffalo population has been attributed to the (1) high rate of slaughter, (2) increase in farm mechanization, (3) shortage of grazing land, (4) shortage of farm family labour, (5) price of live buffaloes. It is envisaged that this alarming trend could lead to extinction unless effective measures are taken rapidly by the Government of Thailand. Though buffaloes played a very prominent role in providing draught animal power (DAP) in crop production under rainfed condition, this role has not been replaced very much by mechanization. It appears that raising buffaloes for meat is becoming more promising. At the same time, the use of manure as fertilizer for crops has also been profitable. Although the role of buffaloes has changed in small farm systems, buffaloes production in general is still not regarded as a distinct enterprise, rather being as integral part of crop production systems.

A programme on genetic improvement of swamp buffaloes for use as dual purpose animal (meat and draught) is in place. This programme has been directed to solve two basic problems, (1) the decrease in number and (2) the reduction in mature body weight and size of buffaloes under small farm production. The objective of performance listing is to identify superior buffaloes for cows and bulls as replacements. The criteria for performance testing are based on the average daily gain two year adjusted weight, height and general appearances of the buffaloes. Practically, the top ranking bulls are utilized for semen collection, the 3rd to 6th for bull replacements at buffalo breeding stations and the rest for farmers' extension programmes. The proven females are used for replacements at the DLD stations.

Reproduction and growth performance of buffaloes at the matured herd were evaluated as the result of genetic improvement programmes during 11 years (1983-1993). With regard to reproductive performance, the age at 1st calving has been reduced to 3.5 years, calving interval to 487 days, conception rate to 80.5%, calving rate to 76.9% and the calf crop to 70%. Thai government appointed a commission in 1998 to develop a national strategic plan for the development of beef cattle and buffalo raising to increase the beef production in the country.

Introduction

Buffaloes have had a great role in Thai rural economy since time immemorial. They contribute animal power for crop production, a source of animal protein for rural consumption, manure for soil fertility and household security as savings. The benefits of buffaloes have been well recognized by rural people, but much less by city dwellers or policy makers or animal scientists. Due to economic circumstances of small farmers, large numbers of buffaloes in many farms were sold for cash in order to meet the household needs or for survival in difficult economic circumstances. Currently, the fast decline in buffalo numbers has become one of the critical issues facing the Thai government, because of its concern for the subsistence farmer and the need to improve the living standards of rural people.

Buffalo population

Thailand used to have the second largest swamp buffalo population in the world. But the buffalo numbers declined drastically during the last decade from approximately 4.7 million in 1990 to 1.9 million in 1998, according to the statistics of the Department of Livestock Development (DLD) shown in Table 1. Furthermore, the estimate from the same source on the number of buffaloes for 1999 was less than one million. Table 1 also shows the distribution of buffaloes by regions during 1930 to 1998. A larger number of buffaloes, approximately 83%, were found in the Northeast, where most agricultural production is under rainfed conditions. The Thai buffalo belongs to the swamp type. The majority are grey to black in colour (90-95%), while the rest are white. Most of the buffaloes are raised by small farmers in rural areas. Some of their characteristics are summarized in Table 2.

Table 1. Buffalo population in Thailand by regions during 1990-1998.

Year	Regions				Whole kingdom
	Central	Northeastern	Northern	Southern	
1990	303,329	3,735,930	564,669	90,362	4,694,290
1991	324,752	3,817,452	566,360	96,507	4,805,071
1992	310,090	3,792,678	532,975	92,528	4,728,271
1993	287,048	3,908,575	524,790	83,733	4,804,146
1994	255,971	3,460,440	431,025	77,355	4,224,791
1995	228,023	3,009,063	398,562	74,413	3,710,061
1996	153,892	2,258,494	236,686	70,602	2,719,674
1997	135,618	1,911,639	187,095	59,586	2,293,938
1998	109,806	1,614,867	171,371	55,024	1,951,069
1999					900,000E

Note: E is the estimated number

Source: Department of Livestock Development (1998)

Table 2. Some characteristics of Thai swamp buffalo in small farms

Traits	Unit	Range
Calf crop (weaned)	% per year	23-82
Calving interval	Days	370-670
Death loss (birth to weaning)	%	10-30
Death loss (weaned calves and older calves)	%	2-3
Renlacement rate (cow herd)	%	6-7
Age of cow at replacement	Years	16-17
Land use per A.U	Hectare	0.15-0.20
Weight at birth	Kg	26-38
Weight at weaning (3 months)	Kg	125-150
Weight of cows	Kg	350-450
Weight of bullocks at maturity	Kg	450-650
Age at first calving	Years	3.5-4.7
Dressing percentage (bullocks)	%	43-51
Post-weaning daily gain	Kg	0.34-0.75

Source: Chantalakhana (1985)

At present, the declining trend in the number of buffaloes in Thailand is reaching an alarming level, indicating a move towards extinction, unless effective measures are taken by the Government. The major factors affecting high reduction in buffalo numbers are as follows:

High rate of slaughter

Villagers in remote areas have gradually sold their draught buffaloes, that are not used for work. These buffaloes, both male and female or even pregnant females, go through different channels of middle-men, and finally end up in slaughter houses. It was frequently witnessed that about 50 per cent of the slaughtered females were pregnant. The buffalo foetus is very popular for consumption among some Thai groups, due to certain beliefs. This practice impedes fertile females to reproduce more offspring.

Increase in farm mechanisation

There has been a transition from the use of buffaloes to farm machinery, for crop production by small farmers in rainfed areas due to the government promotion programme. In villages, where draught buffaloes are used for work, fewer farmers still keep draught buffaloes, while many farmers purchased or rented a two-wheel tractor for agricultural works for a variety of reasons. Major sources of money for small farmers to buy mechanical tools come from credit offered by the BAAC (Bank of Agriculture and Agricultural Cooperatives) plus cash from selling their own buffaloes (Bunyavejchewin *et al.*, 1994).

Shortage of grazing land

Normally buffaloes are allowed to graze in the paddy fields, scrub forests on upland areas, highway shoulder, rice bund or communal grazing land, whatever available during different seasons. Providing a small plot of land for grazing is not practical for rainfed farmers any more. This is due to the booming price of lands before the economic crisis in the year 1997. Many farmers sold some plots of their land mostly to the city dwellers. In addition, the scarcity of grazing lands always occurs during the cropping season (rainy season) as most lands are used for crops.

Shortage of farm family labour

There has been the migration of farm family members at working age, to urban areas to work in factories such as those in Bangkok, Rayong, etc. Only the old folks remain at home to tend to farm work. Some farmers have to hire labour needed from outside. No surplus farm labour in the families tends buffaloes.

Price of live buffalo

Farm price of live buffalo was generally lower than that of live cattle, while beef prices from buffalo and cattle are more or less the same. Since buffaloes are not necessary for farm work any more, the lower price of buffaloes has recently discouraged farmers from keeping them. As a matter of fact, farmers could see the comparative advantage of keeping crossbred cattle over buffalo in terms of income. Many of them have shifted from rearing buffalo to cattle.

Changing Role of Buffaloes at Small-farmer Level

Formerly, buffaloes played a very prominent role as draught animals in crop production under rainfed conditions, especially in paddy production. At present, this role is very much replaced by mechanisation. Only a small number of farmers and specific groups of people in certain areas, for example, some hill tribes in the North, in rural villages still use buffaloes for work. The decline in buffalo numbers has resulted in a significant rise in price of buffaloes. Villagers currently are trying to keep more female buffaloes on their farms, because they can earn a higher income by producing more offspring for sale. It appears that raising buffaloes for meat purposes in small

farms is becoming more promising. At the same time, the use of manure as fertilizer for crops gives benefits for soil fertility, a system that farmers have practiced for a long time. Although the role of buffaloes has changed in small-farm systems, buffalo production in general is still not regarded as a distinct enterprise, but rather as an integral part of crop production systems. The typical small-farm buffalo production system under village conditions has been almost the same as characterized by Chantalakhana (1985). The system is complementary to crop production and utilises non-marketable farm products, marginal land for grazing, family labour, requires minimal cash input; and simple and traditional technology and is subject to a very low degree of risk.

Among the market prices of animal meats, beef is the highest, as compared with pork or chicken. Due to improved education and family income, among middle-income groups, the demand for beef consumption keeps rising. According to statistics of the Department of Livestock Development (1998), a large amount of quality beef was imported into Thailand, for example in 1998, over two thousand tonnes, valued at over 175 million baht or almost five million US dollars, mainly from Australia, USA and New Zealand. It is necessary for Thailand to increase beef production from buffalo as well as cattle, especially under the current situation, when the price of live buffalo is relatively high. A review (Wanapat *et al.*, 1994) of buffalo research studies on nutrition and feeding by national and international scientists, showed that buffaloes when compared to beef cattle appeared to be quite efficient meat producers under less optimal feeding conditions, using low quality feeds, such as farm wastes and by-products at small-farm level in rural areas.

Genetic Improvement Programme

A programme on genetic improvement in swamp buffaloes for use as dual purpose animal, i.e. for meat and draught, was established since 1975. This programme which is part of the National Research and Development Center Project, centered at the Department of Livestock Development (DLD) was a collaborative effort of DLD and Kasetsart University at early stages, but later included Khon Kaen University and other institutions. It intends to solve the two basic problems on the decrease in number and the reduction in mature body weight and size of buffaloes under small-farm production (Chantalakhana and Bunyavejchewin, 1990). The DLD designated the Surin Livestock Station as the National Buffalo Breeding Center, where various research activities related to buffalo production would be carried out in conjunction with the selection breeding programme. Only about 300 buffalo cows in the national herd have been maintained in accordance with available facilities. The selection of the top ten buffalo weaners (8-12 months of age) from Surin Station, both male and female, has been conducted based on their 240 day adjusted weight, height, average daily gain, and general appearance. Three groups of weaners a year were sent to Lamphayaklang Livestock Research and Development Center to undergo the performance testing in the period of one year.

The objective of performance testing is to identify superior cows and bulls as replacement for Surin station, and other buffalo stations and the surplus for sale to farmers (Konanta, 1989). A committee consisting of experts from the institutes mentioned, had been appointed before the programme started. The plan of the testing procedures is to be applicable to small farmers and considerably similar to their feeding regimes. Concentrate supplements fed to the calves consisted of cheap and locally available ingredients in order to allow genetic expression of the animals. The criteria of performance testing are based on the average daily gain (at the moment 350 and 400 g/day for female and male), two-year adjusted weight, height and general appearance of the buffaloes. The proven animals are assigned for different uses. Practically, the top two ranking bulls are utilised for semen collection, the third to sixth as bull replacements in buffalo breeding stations and the rest for the farmers' extension programme. The proven females are used as replacements at the DLD stations and culled animals are sold to the market.

Reproductive and growth performance of buffaloes at the national herd were evaluated and the results of the genetic improvement programme during 11 years (1983 to 1993) of performance testing (Intaramongkol, 1995) are shown in Table 3 and Table 4.

Table 3. Reproductive performance of swamp buffaloes at Surin Buffalo Breeding Center

Traits	1976-1983	1986-1989	1990-1993
Age at first calving, year	4.5	3.7	3.5
Calving interval, day	587	526	487
Conception rate, %	67.5	75.0	80.5
Calving rate, %	60.6	70.0	76.9
Calf crop, %	57.2	65.0	70.5

Source Adapted from Intaramongkol (1995)

Table 4. Growth performance of swamp buffalo at Surin Buffalo Breeding Center.

Traits	1976-1982	1983-1989	1990-1993
Birth weight, kg	28.4	30.0	29.6
Weaning weight at 240 days, kg	121.0	141	147
Pre-weaning gain, (g/head/day)		459	491
Two-year adjusted weight, kg	268.0	355	373
Post-weaning gain, (g/head/day)		408	430

Source Adapted from Intaramongkol (1995)

A few years ago the DLD expanded the number of buffaloes to 4 or 5 other stations, besides the three main buffalo stations (Surin, Lamphayaklang and Surat Thani stations) to respond to the increasing demand of quality bulls for use in the country.

Strategic Plan for Buffalo Production Development

By the end of 1998, the Thai government appointed an *ad hoc* committee to develop a national strategic plan for the development of beef cattle and buffalo raising, in order to increase beef production to meet the demand for consumption in the country. The plan was accomplished and approved in 1999. There are 8 strategies for implementations i.e. (1) the management of animals passing through the border, (2) the improvement of laws and regulations that obstruct beef cattle and buffalo development, (3) improving marketing systems, (4) improving and standardizing slaughter houses, (5) strengthening beef cattle and buffalo production through extension and development, (6) establishing a fund to promote cattle and buffalo development, (7) to slow-down high rate of decrease in numbers of Thai swamp buffaloes and native cattle, and (8) to increase support for research and development to increase the efficiency in cattle and buffalo production.

To strengthen buffalo production, the development programmes of the government are primarily targeted to promote villagers who still raise buffaloes on farms for any purposes in order to increase animal number. The extension programmes to promote buffalo raising for meat and draught purposes as well as services, put the incentives directly to farmers' groups at village level in Northeast Thailand. Government has funded such urgent programmes as mentioned in order to increase beef production, providing draught buffaloes for farm works to small farms, hopefully to slow down the decline of buffalo population.

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BUPFALO PRODUCTION RESEARCH AND DEVELOPMENT IN VIETNAM

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Abstract: Traditionally, swamp buffaloes are allies of Vietnamese farmers in working in the rice fields. Today, although tractors are increasingly used for land preparation in many areas of Vietnam, swamp buffaloes are still raised for work, and also for meat and for other income generating sources. Murrah buffaloes and F₁ crossbreeds are also raised for milk and meat. Their performance is good and their potential importance is increasing. There have been many promising results obtained from buffalo research and development. Despite these, buffalo production development has slowed down in the recent years, due to reasons such as perceived backwardness of buffalo production by farmers, a reduction of grazing lands, agricultural mechanization, limitation of resources for research and extension, etc. There is a need for local and international co-operation to provide financial and technical support to improve the situation.

Keywords: Swamp, Munah, F₁ crossbred buffalo, research, development.

Introduction

The Swamp buffalo is traditionally an important animal to farmers in Vietnam, where it is used to prepare and cultivate the rice fields and provide meat. Murrah buffaloes have been imported and raised in some regions of the country to investigate their potential in local areas. However, their development has been limited due to lack of research resources and the fact that results from local swamp buffalo have showed promise. Farmers in Vietnam have traditional experience in buffalo raising, but techniques are primitive. There have been some efforts in buffalo production research in areas such as nutrition, reproduction and disease prevention, but the improvements in performance have been limited due to lack of research resources and development. Zoo-technical practices are hardly used in rural areas to exploit their considerable potential. Therefore, these potentials should be realized and suggestions for future research are necessary, to help farmers who raise buffaloes under sustainable farming systems. This paper reviews the results of buffalo research and development in Vietnam in recent years.

Present Status of Buffalo Production

The total buffalo population in ASEAN countries decreased slightly (-0.59% per year) from 1990 to 1999. Some ASEAN countries have seen however an increase in their buffalo population during this period i.e. Laos, Myanmar, Philippines and Vietnam, but in other ASEAN countries their populations are decreasing. Vietnam is ranked a country with a high buffalo populations in ASEAN (Table 1). Although there has been a small annual increase of buffalo population (0.56% per year), there has been a serious reduction of the buffalo population in the Mekong and Hong river deltas (Thu, 1997^a), while the cattle population has steadily increased over the recent years. More than 50% of the total buffalo population is found in the mountainous areas of the Northern provinces, because of the existence of large grassland areas there (Table 3). Rice production plays a major role in the agriculture of Vietnam (Table 4), and therefore, draught power required for production in small farms is still very important. Vietnam is also a country producing and consuming more buffalo meat than beef from cattle (Table 2 and 5). Buffalo milk production in Vietnam is limited due to the small number of Murrah buffaloes, while milk production from cattle is increasingly developed, mainly because of many active projects to improve cattle milk and meat performance.

Table 1. Change in buffalo population in ASEAN countries from 1990 to 1999

	1990	1993	1996	1999	1990-1999 Change (%)
Cambodia	736,000	824,000	743,900	693,660	-5.75
Indonesia	3,335,080	3,056,510	3,171,180	3,145,150	-5.69
Malaysia	205,160	193,800	157,000	150,000	-26.9
Thailand	5,094,270	4,804,000	3,700,000	3,500,000	-31.3
Laos	1,071,760	1,130,720	1,168,230	1,286,000	20.0
Myanmar	2,061,000	2,111,000	2,265,620	2,379,000	15.4
Philippines	2,764,950	2,575,760	2,841,280	3,006,000	8.72
Vietnam	2,854,100	2,960,800	2,953,700	2,999,500	5.09
ASEAN	18,124,310	17,658,590	17,002,940	17,161,310	-5.31

Source: FAO, (1999) adapted by Thu (2000)

Table 5. Buffalo meat production in some ASEAN countries in 1999

Country	Buffalo meat (MT)	Beef and Buffalo meat (MT)	% Buffalo meat/ beef and buffalo meat
Cambodia	12,640	53,680	23.5
Indonesia	45,000	399,000	11.3
Malaysia	4136	22,402	18.5
Thailand	79,500	212,900	37.3
Laos	19,200	37,700	50.9
Myanma	70,230	121,030	16.7
Philippines	57,350	223,170	25.7
Vietnam	104,920	196,920	53.3
Total	342,976	1,266,802	27.1

Source: FAD (1999) adapted by Thu (2000)

MT - metric tonnes

Table 3. Distribution of the buffalo population in different regions of Vietnam

Region	Percentage
Mountainous and up-land areas in the North	51.8
Hang river delta	8.60
Central part	28.2
South-eastern provinces of the South	6.38
Mekong river delta	4.96

Source: Lich, (1996)

Table 4. Food crop distribution based on total cultivated land area (8,755,200 ha) in Vietnam.

Crop	Cultivated area ('000 ha)	% of total cultivated area
Rice	6,475.4	74.0
Maize	478.0	5.46
Sweet potato	404.9	4.62
Cassava	283.8	3.24
Annual industrial crop	584.4	6.67
Vegetable and beans	445.4	5.09
Potato	25.7	1.0

Source: Ly *et al* (1995)

Table 5. Buffalo meat as compared to cattle meat production in Vietnam from 1990 to 1999

Year	Buffalo (head)	Cattle (head)	Buffalo meat	Beef (Mt)	Beef + Buffalo meat (Mt)	Buffalo / total buffalo & cattle (%)	Buffalo meat/ beef & buffalo meat (%)
1990	2,854,100	3,116,900	89,225	75,000	164,225	47.8	54.3
1993	2,960,800	3,333,000	95,826	75,000	170,826	47.0	56.1
1996	2,953,700	3,800,300	92,450	83,000	175,452	43.7	52.7
1999	2,999,500	4,040,000	104,920	92,000	196,920	42.6	52.3

Source: FAO (1999) adapted by Thu (2000)

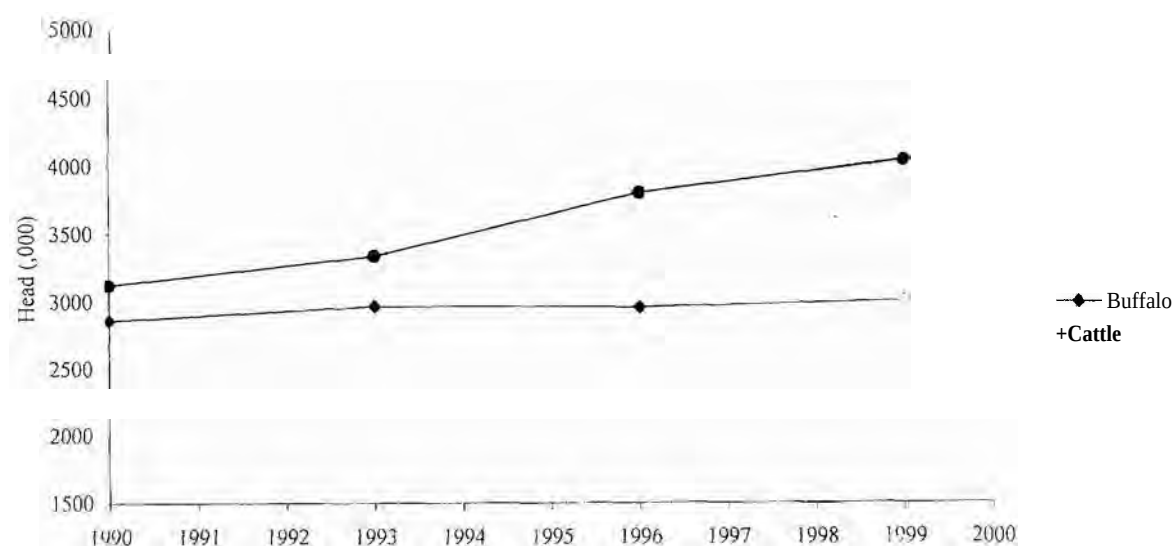


Fig 1. Changes in buffalo and cattle populations in Vietnam in recent years (FAO, 1999)

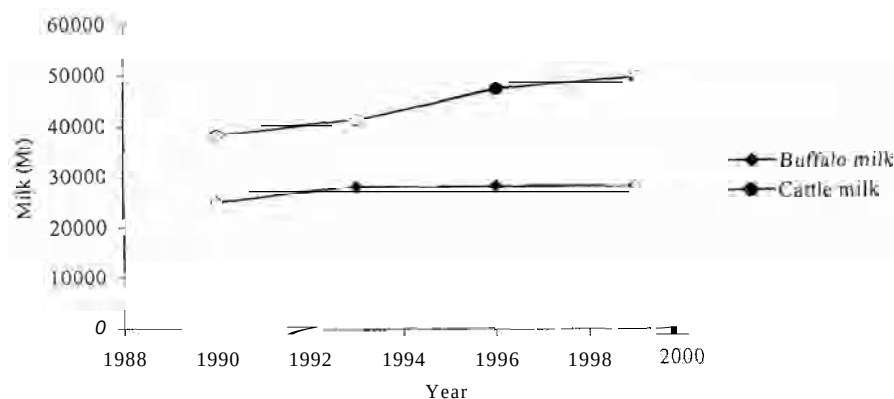


Fig. 2. Buffalo and cattle milk production in Vietnam (FAO, 1999)

Breed Characteristics and Productivity

Breeds

The dominant buffalo breed in Vietnam is the swamp buffaloes. Murrah buffaloes were imported from India to improve milk production of the local buffalo through crossbreeding. Table 6 shows that there are differences in the body size of the swamp buffaloes in different regions of Vietnam, which can be explained as due to the influence of different climates, feeds, management, etc. However, the appearance of swamp buffaloes in Vietnam is similar to that of the swamp buffaloes in other ASEAN countries and China. Generally, the size of swamp adult buffalo is smaller than that of Murrah buffalo, while the F_1 crossbreed (Murrah x Swamp) being intermediate in size. Swamp buffaloes in the Mekong delta are larger than in other regions, and buffaloes in Dong Thap province of this region are the biggest in Vietnam with reported average live weights of 593 kg for females and 706 kg for males (Thu, 1987). Daily weight gain from birth to 3 years of age is about 300g for swamp buffaloes under village feeding conditions and is higher for Murrah and F_1 crossbreeds.

Reproductive Characteristics

The reproductive characteristics of buffaloes in Vietnam have been recorded by several authors, (Hoang, 1978; Thac, 1979; Thu, 1987 and Sanh, 1996). The reproductive performances of swamp buffaloes are variable and being lower than those of the Murrah. Limitations of their reproductivity are attributed to lack of improved conditions such as nutrition, selection, disease and management. The survival rate of live calves after weaning for the swamp buffalo ranged from 80-96%, with an average of 96% for the Murrah. Calving interval was shorter in the Murrah (509±98.6 days) than in the swamp and F_1 crossbreeds (550 days). Seasonal births are an obvious feature in swamp buffaloes, which depend on working seasons, resting time and nutritional conditions. Sanh (1996) reported that Murrah buffaloes showed oestrus all year round, but oestrus in cows was affected by season, with higher rates from October to March. This may be caused by the local climate (hot and dry) during the rest of the year.

Table 6. Basic measurements and live weight of the adults of Swamp, Murrah and F_1 crossbred buffaloes in different regions of Vietnam

Criteria	Mekong Delta ⁽¹⁾	South-eastern Provinces ⁽²⁾	Central Part ⁽³⁾	Northern Provinces ⁽³⁾	Murrah, ⁽⁴⁾ at Song Be province	F_1 crosses (in the North)
Female						
Height at wither (cm)	127	126	121	118	131	
Length of body (cm)	141	132	128	127	143	
Heart girth (cm)	192	193	191	180	195	
Live weight (kg)	458	434	417	358	457	435 ⁽⁵⁾
Male						
Height at wither (cm)	131	129	129	121	138	
Length of body (cm)	143	135	136	133	154	
Heart girth (cm)	198	197	198	190	207	
Live weight (kg)	494	464	494	428	595	470 ^{(6)*}

Source: ⁽¹⁾Thu (1987), ⁽²⁾Hoang (1978), ⁽³⁾Thac *et al.* (1979) and ⁽⁶⁾Thac *et al.* (1996), respectively and ⁽⁴⁾Xuong and Thu (1981) and ⁽⁵⁾Sanh (1996) adapted by Thu (1997^b and 2000).

* At 3 years of age

At the research stations, semen of Murrah bulls is collected, evaluated and buffalo cows showing heat inseminated. Signs of heat were identified with the help of detector bulls. The timing of insemination to ensure good conception rate ranged from 0 to 4 hours before and after the cows showed signs of being ready for mating. In the villages, farmers usually let their own swamp

buffaloes into the fields for natural mating. The availability of artificial insemination (AI) services for buffaloes in the villages is a rare occurrence.

Meat, Milk and Work Performance

Data on productive performance of buffaloes in Vietnam are presented in Table 7. The mean carcass weight of swamp buffaloes reported from the North of Vietnam was 187 kg with a live weight of 428 kg (Thac, 1979). The mean carcass weight of the swamp buffaloes in the Mekong delta was higher than that of the buffaloes of the Northern provinces due to the higher live weight. These measurements were obtained from buffaloes raised under village conditions. Thac *et al.* (1996) stated that F_1 crossbreeds raised under the same conditions as the swamp buffaloes, showed better weight gains and feed utilization. Similar results were also reported by other authors, (Nachaingmai, 1995; Momongan, 1994 and Chantatakhana, 1999). Recently, Thu (1997^a) reported that the average milk yield of swamp buffaloes, from the first to the fifth month of lactation in the Mekong delta were 1.50 kg per day, and that the average milk fat was 11.9% with *sacciolepis indica* and 8.68% with *eleocharis dulcis* and rice straw diets under village conditions. Average milk yield of Murrah buffaloes was 5.50 kg/d reported by Xuong (1981). The F_1 crossbreeds gave daily milk yields and fat contents in between those of Murrah and swamp buffaloes, (Sanh, 1996). In the Southern part of Vietnam swamp buffaloes are used for work in pairs, while they work singly in the North. Ploughing capacity of the swamp buffaloes in the North, was 630 m²/half day/animal (Thac, 1979). In Murrah buffaloes the carcass percentage and milk yield were higher than those of swamp buffaloes, although the milk fat content of the Murrah was lower. Results of recent studies showed that Murrah buffalo cows could be used for work and for milk production (Thu, 1996).

Table 7. Meat, milk and working performance of buffaloes in Vietnam

Criteria	Swamp (in the South)	Swamp (in the North)	Murrah	F_1 crossbred
Meat production*				
Live weight (kg)	592 ⁽¹⁾	428 ⁽⁷⁾	374 ⁽³⁾	264 – 422 ^{(7)**}
% carcass/live weight	46.3 ⁽¹⁾	43.6 ⁽⁷⁾	54-67 ⁽³⁾	49.1 – 52.9 ^{(7)**}
% Meat/live weight	36.3 ⁽¹⁾	34.1 ⁽⁷⁾		39.1 – 43.5 ^{(7)**}
Milk production				
Lactation period (day)		210 – 360 ⁽²⁾	236 ± 57.3 ⁽⁴⁾	292 ± 27.5 ^{(8)***}
Milk yield (kg/day)	1.50 ⁽⁶⁾	2.20 – 3.45 ⁽²⁾	5.55 ⁽⁴⁾	3.50 ^{(8)***}
Milk fat (%)	8.7 – 11.9 ⁽⁶⁾	8.31 – 15.0 ⁽²⁾	7.36 ⁽⁵⁾	7.02 ^{(8)***}
Milk protein (%)	4.4 – 4.9 ⁽⁶⁾	–		4.01 ^{(8)***}
Working capacity				
Draft force (N)		560 – 600 ⁽²⁾	450 – 500 ⁽⁴⁾	690 – 750 ⁽²⁾
Ploughing (ha/pair/day)	0.30 ⁽¹⁾	0.13 ⁽²⁾	–	0.12 – 0.13 ⁽²⁾
Harrowing (ha/pair/day)	0.73 ⁽¹⁾			

Source: ⁽¹⁾ Thu (1987), ⁽²⁾ Thac *et al.* (1979), ⁽³⁾ Ognjanovic *et al.* (1970), ⁽⁴⁾ Xuong (1981) and ⁽⁵⁾ Thu (1979), ⁽⁶⁾ Thu (1997^a).

⁽⁷⁾ Thac *et al.* (1996) and ⁽⁸⁾ Sanh (1996) adapted by Thu (2000)

* For both males and females

** For castrated and non-castrated males from 15-24 months

*** Raised under village conditions with grass as the sole diet.

Research and Development

Local feed resources and urea-treated rice straw

The main feeds for buffaloes and cattle are natural grasses from grasslands, planted grasses in pastures, crop residues and other tree leaves. However, buffaloes are usually fed grasses and crop

residues of poor nutritive value compared to those for cattle, due to the tolerance of buffaloes to poor and less digestible diets. Nho (1998) stated that in the Northern mountainous region, buffaloes are mainly fed natural grasses, Ruzi grass (*Brachiaria ruziziensis*) was reported to be a feed with great potential for Murrah buffaloes in the dry areas (Khong *et al.*, 1995). Grasses and water plants are essential feeds for swamp buffaloes in acid soil areas. Their nutritive value and digestibility have also been evaluated (Thu, 1997^c). A huge amount of rice straw is produced after each harvesting season in Vietnam. It is used for feeding buffaloes and cattle, litter, mushroom growing, burning in fields, cooking, etc. Some on-station and on-farm research with urea-treated rice straw (4% urea) for dairy and working buffaloes gave good results in improving the nitrogen content in straw (increasing from 70.1 to 142.4% compared to the non-treated rice straw). Other advantages of the technique are higher animal consumption, it is a simple technology, easy to apply and results in work and yield improvements. This technique has been successfully applied in dairy production. However, in villages the adoption of the technique by farmers is still poor for several reasons, such as farmers' feeding habits, low performance of local buffaloes, the cost and labor spent, low profit, etc. Devendra (1991) and Owen and Jayasuriya (1989) also stated that unfortunately, farmer's uptake of the technique has generally been disappointing (Dolberg, 1995).

Multi-nutrient blocks and other supplements

Multi-nutrient blocks have also been studied as supplements for buffaloes in Vietnam since 1985. Although, many positive results in cattle have been reported (An & Man, 1991, Dat, 1991 and Chinh *et al.*, 1993) the licking blocks are not widely accepted by farmers in the rural areas due to the eating habits of Swamp buffaloes (taking long time to train the animals to lick, and low intake), lack of buffalo housing, clumsy blocks and difficulties in transportation. However, the soft blocks (cake) are becoming increasingly popular for improving the condition of draught buffaloes, during the working seasons (Thu *et al.*, 1993). Recent studies have shown that there is a great potential for improving the quality of the cakes, as well as its use for supplementation due to the ease of feeding, increased intake, and positive effects on performance (Thu and Preston, 1999). In the urban areas, there are a few dairy buffalo farms, but they mainly rely on concentrates for supplementing lactating buffaloes. This situation is similar in the dairy cattle farms.

Sansoucy (1995) stated that the degree of technology adoption at farm level varied considerably with local conditions; characteristics of the basal diet, availability and cost of different ingredients; production systems, end product prices and marketing capacity. Wanapat (1991) concluded that high quality feed blocks together with low-quality roughage such as rice straw could significantly increase intake, ruminal NH₃-N and TVFA concentration in buffaloes. Some on-station and on-farm trials on the use of urea-treated rice straw, together with urea-molasses cake to supplement dairy buffaloes gave better results for growth rate (0.60 kg/d vs. 0.31 kg/d), and milk yield per day increased by 14.1% compared to that of buffaloes without cake supplementation. For working buffaloes supplemented with 5.0 kg of urea-treated rice straw and 0.46 kg cake per day, the change of body weight, physiological values and ploughing capacity was significantly improved as compared to buffaloes supplemented 8.0 kg urea-treated rice straw and control animals. Chowdhury and Huque (1995) favoured another form of supplement called urea-molasses straw (straw enriched with 3% urea and 15% molasses), which they found to be more promising compared to the urea-molasses block during field application. Urea-molasses supplementation has been studied for enhancing the buffalo performance in terms of technical, economical and environmental aspects. Several studies on *Sesbania grandiflora* leaves and natural grasses were also carried out to provide alternative supplementation for swamp buffaloes when fed rice straw merely during the dry season (Thu and Preston, 1999).

Draught buffaloes and tractors

An on-farm survey carried out in 1989 in six districts in alluvial regions and six districts in brackish regions of the Mekong delta, focussed on the productivity and utilization efficiency of buffaloes as

draught animals. It was found that in the brackish region, the performances of buffaloes were inferior to those in alluvial regions in terms of growth, reproduction and draught capacity. This was explained in terms of the good green feeds and fresh water available in the alluvial regions. In a comparison of the efficiency of the use of a pair of buffaloes and one tractor based on profit produced over the investment, it was shown that buffaloes were 2.6 times more efficient than tractors. The result suggested that small-holder farmers in the Mekong delta with low incomes could get a good profit from their investments in buffalo production (Thu, *et al.*, 1993).

In recent years, when the free market policy of the Vietnamese government came into effect in Vietnam, the number of buffaloes in the Mekong river and Hong river delta declined largely because of increased use of tractors, increased land areas under cultivation and farmers' expectations that tractors would reduce their work load and give higher profits. The latter has caused a reduction in grazing lands. Despite this, a participatory rural appraisal in Mekong delta in 1994 showed that many farmers still continue to raise buffaloes for their own land preparation, to ensure timeliness of seeding, and for profit from the sale of calves and meat (Ogle *et al.*, 1994). In fact, in many cases farmers had sold buffaloes to buy tractors, and then sold tractors to buy buffaloes for work again due to the limitation of farmers in their understanding of the use of machines and underestimation of the cost of repairs (Thu *et al.*, 1995). Pearson (1993) reported that there are many areas of the world where traditional draught animal power is now being replaced by mechanized power. In parts of East Asia, mechanization has been rapid over the last ten to fifteen years and tractor use for example has more than doubled from 1975 to 1985 in China, India, Malaysia and Vietnam. Nevertheless, there are many situations where it is difficult to see farmers ever being able to adopt mechanical power to replace animal power, either due to the difficult terrain or high costs. Results of recent studies clearly showed that the returns were economically higher in using draught animals as compared to the use of tractors, both in Asia and Africa, when cultivated land area was less than 3 hectares (Pearson, 1996). Thus the working buffaloes will still have an important role for small-holder farmers. Duc (1998) reported that there was a reduction of 37% in the total cost of rice production when using buffalo draught power for cultivation and the wastes for fertilization in the Southeastern provinces of Vietnam as compared to using tractors.

Studies on embryo transfer, reproduction and breeding programs

Frozen semen of Murrah bulls was successfully produced for AI With the technical supports of Indian scientists and technicians (Sanh, 1996), but it is still poorly developed. In contrast the AI services with frozen semen for cattle in villages are widely developed, due to several active projects available for improving cattle productivity. On station AI for Murrah buffalo cows is mainly done with fresh semen. Studies on the use of Murrah bulls to mate the swamp cows has been conducted both in the North and the South Vietnam. They showed a good potential, but this was limited in reality because of a lack of financial support. Studies on the histology of the ovaries, superovulation in swamp buffaloes and buffalo embryo transfer were also reported by Nguyen (1997). These will probably be used for improving buffalo production yields and for conservation of their gene resources. Recent studies on the diseases of swamp buffaloes affecting reproductive organs indicated that 21.6% of the total surveyed buffalo cows were infected in the vulva, uterus and ovary, which caused reduced calving rate of swamp buffaloes in the Northern provinces (Thanh and Dung, 1995).

Crossbreeding programs with Murrah and swamp buffaloes have been carried out for years both in the Northern and the Southern provinces. It was reported that the crossbreeds were at least equal in heat tolerance to the local buffaloes and were superior in draught power. Thac (1979) reported that the F₁ crossbreed of local and Murrah buffaloes in the North of Vietnam had a large size, a good growth rate, a higher milk yield than the local buffaloes and good draught power. They were easy to feed under village conditions. However, their impact in the villages of Vietnam has been poor so far. During the past two decades there have been various attempts in different countries such as China, Malaysia, the Philippines, Thailand and Vietnam to cross the swamp buffaloes with the Murrah to produce crossbreeds for draught and milk production (Chantalakhana, 1992). According to Liu

(1978), about 45,000 crossbreeds, between the swamp buffalo and the Murrah, had been produced in Southern China with the intention of producing more milk and meat, in addition to draught power. Sanh (1996) reported that in F₁ crossbred buffalo cows, the calving interval was rather long as compared to that of Murrah cows. However, promising milk yield of $1,030 \pm 118$ kg per lactation was recorded, and milk fat was $7.02 \pm 0.24\%$ under village conditions, Thac *et al.* (1996) also stated that the F₁ crossbred buffaloes have great potential in terms of meat production. However, this should be supported with good programs of selection, breeding, nutrition and disease prevention. Hypothetically, the crossbred buffalo would be ideal for small farmers having poor resources. However, carefully planned breeding programs will be needed to realize the actual benefits of crossbreeding (Khan, 1998).

Dual and multi-purpose buffaloes

In Vietnam, buffalo meat consumption is very popular. Buffalo meat from young animals is usually used for making "Pho" (a noodle soup) in common restaurants for breakfast, because of its tenderness and good taste, while the meat of old buffaloes is sold for making traditional dishes in almost every home. Particularly in the Mekong delta, there is a very popular dish made from old buffalo meat which is called "Trau luoc com me" (buffalo meat and offal are cooked with fermented cooked-rice) and it is usually enjoyed together with some wild water plants and rice wine. People also believe that eating buffalo meat is good for health. However, raising buffaloes for beef is not yet considered by farmers, due to the lack of such a tradition, extensive feeding systems and lack of technical interventions. Chantalakhana (1992) indicated that at this stage, especially in South-east Asian countries, it is questionable whether priority should be given to selection of swamp buffaloes for milk production. However, if the development goal is to improve the nutrition and health of the rural people, through upgrading of swamp buffaloes for household milk consumption, the breeding goal would be to breed a dual purpose animal for both draught and milk production. This ideal would be useful for improving the nutrition of children and pregnant women, because of the reduction of animal protein sources from fish, scavenging ducks, snails, etc, caused by increased use of pesticides for increasing the number of rice crops. Some studies on milking swamp buffaloes in villages showed a potential development based on farmers' acceptance of tradition of drinking fresh milk (Thu, 1997). The multi-purpose use of Murrah buffaloes (work and milk) which was also studied showed promise (Thu, 1990).

Cows of *Bos Indicus* and *Bubalus Bubalis* are truly multi-purpose animals, producing a range of commodities that are important to farmers. The use of multipurpose animals for milk, meat, draught and manure, has shown potential for increasing farm productivity and A study of the use of female buffalo and cattle working a sugarcane crusher in Colombia showed that sugarcane crushing did not have significant effect on the physiology of pregnant and non-pregnant buffaloes and cattle. In lactating animals worked for three hours per day, there was a significant reduction of milk yield (0.45 kg/5.5 kg milk) but not of fat (Thu *et al.*, 1996). However, data collected over two years showed that working non-supplemented cows gave the lowest milk yields when compared with non-worked supplemented and non-supplemented and working-supplemented cows (Pearsor. *et al.*, 1999). The use of poorly-fed buffaloes for draught purposes is not a feasible option for a production system involving the use the lactating cows for draught. Some demonstrations of using buffalo manure for feeding plastic: tube biogas digesters to produce gas for cooking fuel have been carried out, and the effluents of the biogas digesters were successfully used as fertilizers for crops and fruit trees in villages of the Mekong delta (Thu, 1999).

Diseases and prevention

Common diseases of buffaloes in Vietnam are Pasteurellosis, Foot and Mouth disease, Rinderpest, Bloat, Diarrhoea, etc. (Tam, 1985). Hung (1993) reported that liver fluke infestation was a serious disease in some areas in the Mekong delta and this was also confirmed by different authors from the Northern provinces. Blood parasitic diseases reported were Anaplasmosis, Babesiosis and Trypanosomiasis. Murrah buffaloes were more infected with parasites than the

swamp buffaloes (Hung, 1985). In recent studies Huong (1999) reported that there are four *Sarcocystis* species found in buffalo meat in Vietnam of which two are new species, *S. buffalonis* and *S. Dubeyi*. Veterinary networks in rural areas are more developed to vaccinate buffaloes twice a year before the rainy season and dry season and the vaccinations are mainly against Pasteurellosis, Rinderpest and Anthrax.

Constraints

Although the contribution of buffaloes in Vietnam is very important in terms of farming activities, village labour, human nutrition and economy, buffalo production research and development are limited compared to the potential. Reasons for these limitations can be listed as follows:

1. Farmers are wrong in thinking that raising swamp buffaloes is a backward production type while cattle production is being supported as promising for the future.
2. There is a rapid reduction of grasslands as a result of increasing crop cultivation, while farmers still follow the traditional extensive range systems.
3. Lack of research and development resources and, then lack of convincing demonstrations of profitable buffalo projects to improve farmers' production.
4. Lack of conditions and facilities to support development of the buffalo milk and meat industries.

Potential and Prospects

Vietnam has a great potential to develop buffalo meat and milk industries besides draught power, because of the availability of feed resources, labour and markets. Farmers' experiences in buffalo production and the recent positive results of studies also support sustainable production. Buffalo production development in Vietnam has slowed down in recent years and buffalo performance is only improving slowly, while the demands for milk, meat, draught power and fertilizers are increasing, due to an increasing human population and the need for improvement of the family economy and living standards. These are challenges to the development of this animal species. Thus, buffalo production studies should be more technically practical and economically efficient and, applicable techniques and funds for their adoption should be given to farmers more directly. Research and development areas in buffaloes that could be suggested are: improving buffalo performance and recording systems, developing suitable feeding systems, utilizing local feeds, multi-purpose uses, enhancing selection and crossbreeding programs, disease prevention, developing milk collecting and processing systems, improving facilities for buffalo meat industry, facilitating extension services, etc. Local-international co-operation should be considered for supporting techniques, finance and information.

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PLENARY SESSION - III

Country Papers

Discussion

Q. A. Wickremasuriya - What are the common diseases in India, and are high yielding cows more prone to mastitis?

A. S.K. Ranjhan - The common diseases are rinderpest, FMD, HS, BQ, anthrax, mastitis and brucellosis. Mastitis is present in high yielding animals, With regard to brucellosis, an eradication programme is in progress. This involves the adoption of a testing and screening programme.

Q. A. Alexviev - I have observed that you have the Murrah and Meshana breeds in Gujarat. What is the future of these breeds? The Nili Ravi animals are not true to type, they have more Murrah blood.

A. S.K. Ranjhan - The Nili, Ravi and Murrah were of the same stock before separation of the country. After separation, the herds were maintained in the same way until 1960. Thereafter the Nili and Ravi were put together.

Q. B.M.A. Oswin Perera - With regard to the question regarding 48 and 50 chromosomes, no infertility has been found to occur. Earlier, there was concern that there might be unbalanced gametes, but it does not work that way. They have been looking particularly at the males to see whether they may have a higher incidence of infertility, I wonder whether anyone here has any information on this.

Comment. L.C. Cruz - We have been doing cross breeding and follow-up activities on the fertility of males and females. We have 50:50, 75:25 and high blood lines of Murrah x Carabao crosses. We went through the process of analyzing fertility even to the extent of analyzing the semen quality of the males. I would say that the effect of cross breeding on the quality of semen is seen in a higher percentage of abnormal sperms. But as Prof. Jainudeen mentioned, you need only one sperm to fertilize. So, in a population of millions of sperm, the possibility is that there will be little effect on overall fertility of the male. But, when the male is used for AI, there may be some reduction in terms of the semen output. This is our experience in the Philippines.

Q. S.S.E. Ranawana - Do you have any buffalo ranching farms for meat in the Philippines?

A. A. del Barrio - We have only one ranch. The buffalo is mostly kept for milk.

Q. T.N. Jayatilake - You mentioned some very important policy constraints for Carabao development in the Philippines. I think you mentioned the need to develop a more competitive industry. How will you bring about this competitiveness? Is it with local or foreign involvement?

A. A. del Barrio - This is included in the policy statement on trade liberalization. I believe we have to create competition within the Philippines and may be later on, we should consider establishing foreign markets. I cannot say what will happen in the future.

Q. A. Shakhivale - You were saying that the potential for milk production is between 12- 15 l/day. Is this the average or the maximum potential?

A. A. del Barrio - The production of 12-15 l/day is from some records that have been maintained. The production could reach up to 16 l/day in a few animals. The average production with the Murrah is between 8 and 10 l/day. But the national average is between 7 and 8 l/day.

Q. K.C. Somapala – Dr. Bandara, you were speaking of several management systems and also a new system. What is this new system?

A. B.H.W.M.U.S. Bandara - In the western coastal region, where you do not find large herds and the fodder availability is low, one cannot practice the traditional extensive management system. A system close to the extensive system has to be practiced in these areas.

Q. K.C. Somapala - You also spoke of the genetic degradation of animals. Have you any scientific evidence of this taking place under natural breeding conditions?

A. S.S.E. Ranawana – This conclusion has been made on the basis of empirical observations, but you cannot deny certain facts that are evident. We know that the best animals are either castrated or slaughtered for meat and there is no selection of bulls for mating. The bulls that serve are those that remain. This has been reported from other countries as well. There is no hard data to support these observations.

Q. A.D.N. Chandrasiri - What are the measures that you would suggest to overcome this problem?

A. B.H.W.M.U.S. Bandara - Our policy is to decrease the herd size and upgrade to produce a dual-purpose animal. We will have to do selection, locate the best animals and preserve them.

Comment. K.C. Somapala - Coming back to my question; I would like to say that I have been working for some time with farmers who have large herds in the dry zone. When we ask these farmers, they say that the milk yields have increased.

Q. S.K. Ranjhan - The most serious problem we encounter is the reduction in the buffalo population. In 1980, Thailand had 6 million buffaloes, but 20 years later the population has come down to 1 million. There are other countries like Malaysia and China, where the population has declined. Mechanization will come whether we like it or not. If we keep the buffalo only as a draught animal, it will become extinct. In the Philippines too, the population was declining, but there has been a change in Government policy to arrest the decline by developing a multi-purpose animal, China too has changed towards development of a multi purpose buffalo. Perhaps this will reverse the decline.

A. P. Skunmun - I agree with you. In 1971, we imported some Murrah buffaloes to Thailand in order to make our small farmers to raise buffaloes for milk, but they did not adopt them, because we have no milk drinking habit. Still, we produce only 30 percent of milk for consumption. Perhaps if the people will take up to drinking buffalo milk, we can do it.

Q. S.S.E. Ranawana - How much of your rice is cultivated under irrigation and how much is grown under rainfed conditions?

A. N.V. Thu - In the Mekong Delta areas we have a lot of water, and in other similar areas too we have irrigation systems. But in the mountain regions, we have upland rice cultivation.

Q. S.S.E. Ranawana - Can you explain a little more about the difference between the hard and soft UMMB? You mentioned that the soft block is more popular.

A. N.V. Thu – When the lick block was first introduced and we demonstrated its use, we had no problems with dairy cattle. But swamp buffaloes did not lick it and we failed because we worked with farmers who had not trained the buffaloes. We then came up with the soft block, because it can be fed directly even as a solution. For buffaloes we also make a thick solution which can be applied on rice straw. This is a very flexible method that gave good results when urea molasses is fed with straw.

BIOTECHNOLOGY: FUTURE ROLE IN BUFFALO PRODUCTION AND HEALTH

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Abstract: This paper reviews the current and emerging biotechnologies in cattle and their relevance to research in production and health of the Asian buffalo (*Bubalus bubalis*). Modern biotechnology was originally restricted to molecular biology, genetic engineering and recombinant DNA. However, to be applicable to animal production and health, it has to include reproductive biotechniques as well as procedures such as production-related hormones, modification of rumen digestion, new approaches to disease diagnosis and vaccine production.

Spectacular results could be achieved by production of transgenic animals and clones leading to a lifetime and heritable expression of their effects in the buffalo. However, the desired gene(s) must be identified, isolated and prepared for gene insertion. Traits carrying several advantages could be exploited using these emerging technologies. Reproductive biotechniques, such as sexing and cryopreservation of sperm and embryos are in progress for preserving genomes of superior buffaloes in breeding programmes in many Asian countries, particularly in India.

Suitable rumen microorganisms naturally selected or genetically engineered could be used to develop new feeding strategies to enhance buffalo production on low quality feeds. Growth promoters and regulators from immuno-manipulation and feed enzymes are strategies to be considered to improve growth rates and leaner carcasses, higher milk yields and reduce feed costs. Recombinant technologies for vaccine production and improved methods for disease diagnosis and disease surveillance need serious attention.

Asian countries should launch their own biotechnology research programmes. The use of biotechnology in buffalo research is a costly undertaking that requires long-term commitment of personnel and resources. A substantial increase of funding for basic research for technology transfer in the buffalo is required. Asian countries should seek technical assistance to establish research linkages among institutions engaged in biotechnology within and among countries. The Food and Agriculture Organisation (FAO), the International Atomic Agency (IAEA), and Swedish Agency for Research Cooperation (SAREC) and other international agencies should continue to assist member countries in capacity building of research facilities and training of biotechnologists.

While retaining the Asian buffaloes traditional role with the rural farmer, let us emulate the experiences of buffalo rearing in Italy and South American countries and encourage Asian biotechnologists to apply emerging technologies for the commercial production of milk and meat from this sadly neglected animal.

Keywords: Genetic engineering, recombinant DNA technology

The Asian Buffalo's Plight

The plight of the Asian Buffalo is a sad story. Many Asian Governments regard the buffalo as a "servant" of the rural farmer and that little inputs are needed for its survival in the village environment. Under these circumstances, the buffalo populations in many Asian countries is rapidly decreasing due to mechanisation or by being replaced by intensive production systems such as poultry or swine. Emerging technologies in cattle could increase calf survival, reduce adult mortality, increase reproductive rates, develop new feeding strategies and increase the productivity of the buffalo for meat and milk. This paper reviews the current and emerging technologies in cattle and their relevance to research in production and health of the Asian buffalo (*Bubalus bubalis*).

Emerging Technologies

Emerging technologies include biotechnology and reproductive biotechniques. The science of biotechnology involves the development of biological organisms or their components for commercial or industrial processes, whereas reproductive biotechniques include artificial insemination (AI), embryo transfer (ET) and related biotechniques.

Biotechnology

For centuries, traditional agriculture relied on crossbreeding and hybridisation to improve the quality and yield of crops and animals. Unfortunately, these processes are not only time-consuming and costly, but also sexual reproduction can occur only between individuals of the same species.

Since the discovery that DNA is interchangeable among animals, plants, bacteria or any organism, it is possible to isolate the gene or genes for the traits from one animal and move them into another. The animals modified in this way are called transgenics. Of course, when several genes control a trait, the transfer process is more difficult.

Modern biotechnology was originally restricted to molecular biology, genetic engineering and recombinant DNA. However, to be applicable to animal production and health, it has to include reproductive biotechniques as well as procedures such as production-related hormones, rumen biotechnology, and new approaches to disease diagnosis and vaccine production.

Reproductive biotechniques

Advances in reproductive biotechniques already developed in the buffalo could contribute to genetic improvement. However, the ultimate goal is to produce animals whose hereditary DNA has been augmented by the addition of DNA from a source other than parental germplasm, using recombinant DNA techniques (transgenic animals). Transgenic animals can be created that possess traits of economic importance including improved disease resistance, growth, lactation, and reproduction,

The production of transgenic animals is inextricably linked to development of new reproductive technologies. It is impossible to produce animals containing foreign DNA in their germlines without first manipulating the embryo and transfer-ing it to a recipient animal. Multiple ovulation and embryo transfer (MOET), *in vitro* egg maturation and fertilisation (IVM and IVF), and embryo sexing can be used to upgrade buffalo herds (Jainudeen *et al.*, 1993; Madan *et al.*, 1996). However, when reproductive biotechniques are combined with recombinant DNA technologies, they provide opportunities to efficiently and cost effectively produce transgenic animals and to rapidly improve buffalo productivity.

Biotechnology and Buffalo Production

Since the 1980s, the Food and Agriculture Organisation (FAO) has promoted biotechnology applicable to animal production, particularly in cattle (FAO, 1990; FAO 1999). The issue before us today is how could biotechnology and reproductive biotechniques in cattle contribute to buffalo research in genetics, reproductive efficiency, nutrition, production traits, and disease diagnosis and control?

Animal breeding

Recent advances in biotechnology have revolutionised livestock breeding. Progress in molecular biology and reproductive biotechniques of IVF and micromanipulation of embryos in cattle have contributed to the production of transgenic animals, clones and chimeras. Since genetic gains

through selection and progeny testing are indeed time consuming, alternative approaches - transgenic animals, clones and chimeras - could bring about dramatic results faster.

Transgenic animals

The production of a transgenic animal is a complex process, and involves the following four major steps. (1) The desired gene must be identified, isolated, and prepared for insertion. (2) The host cell must be obtained and prepared for gene insertion, usually a one-cell embryo. (3) The desired gene must be transferred to the host cell. (4) The resulting recombinant embryo is duplicated, and the ensuing multiple embryos are transplanted into recipients. This duplication process allows for the production of multiple offspring of genetically superior animals.

Achieving the goal of transgenic animal production requires the development of efficient and cost effective ways to transfer the selected genes to an embryo. Because of the inefficiencies encountered with the use of viral vectors or microinjection methods to create transgenic livestock, an alternative approach has recently been developed that uses stem cells derived from embryonic or somatic (adult) tissues. Stem cells are normally undifferentiated unlike specialised tissue cells such as muscle, brain, or liver cells. However, stem cells retain their ability to become specialised cells when given the proper stimuli (pluripotent). These stem cells can be used as vectors to introduce selected genes into a host embryo. This method has several significant advantages of inserting DNA at specific, predetermined sites within the genome of the stem cells. Targeted insertion is possible because stem cells have an intrinsic ability to recombine similar (homologous) DNA sequences, which results in the replacement of the endogenous gene with the desired gene.

The gene targeting method makes possible a broad range of phenotypes for transgenic animals that could not be produced economically, using direct microinjection or viral vectors. It allows for endogenous genes to be effectively removed or inactivated. For example, bovine somatostatin is a hormone that inhibits bovine somatotrophin (bST) production; inactivation of this gene would increase endogenous somatotrophin secretion and presumably increase milk production and more efficient growth. If successful, this technology would supplant the need to inject bST to increase milk production. The genes controlling the production of inhibin, the ovarian hormone that reduces ovulation rate, is yet another example.

The advantages of transgenic animals are that they are permanently transformed and newly acquired genes are subject to normal Mendelian inheritance patterns. The transgene is expressed in about 70% of the transgenic animals, but genes controlling production traits are known only for the growth hormone gene.

Cloning

The simplest procedure is to bisect an embryo and obtain two "identical offspring". Alternatively, clones can be produced by transferring nuclei from embryonic cells to previously enucleated oocytes. Clones have been successfully produced in sheep and cattle. Besides nuclear transfer, embryo stem (ES) cells which have the ability to contribute to any or all tissues of the developing animal (pluripotent), as stated earlier, have been used in the production of clones from cattle embryos (First *et al.*, 1994). Production of cloned buffalo embryos through nuclear transfer of buffalo oocytes has been reported at the National Dairy Research Institute, Karnal, India (Singla *et al.*, 1997).

Besides embryonic cells, clones have also been produced from adult tissue. Wilmut *et al.* (1997) successfully cloned an adult sheep by fusing a somatic (mature) cell from the mammary gland of a 6-year old ewe with the enucleated oocyte from another ewe. Dolly, the sheep, was the only successful birth from nearly 300 embryos. A few months later, Kato *et al.* (1995) reported cloning eight calves from cells taken from the oviducts and cumulus, the tissue that surrounds the oocytes

of a single adult cow. The success rate was far higher than for groups attempting to clone large mammals.

Cloning was originally directed to genetic gains in livestock production, but because producing cloned animals for milk or meat is costly, the technology shifted to pharmaceutical applications. Nevertheless, the production of large numbers of elite clones is still needed in animal farming. Emerging technologies such as recycling nuclear transfer embryos, somatic cell cloning, new cryopreservation techniques and automated oocyte harvesting could contribute to the greater use of animal cloning in agriculture (Lewis *et al.*, 1998), but will be applicable only if the technology is economically viable. McClintock (1998) has investigated the cost of a cloned embryo for various purposes. An embryo would cost \$30 for a small farm, 5300 for clones of purebred female embryos and \$3000 for male clones.

Chimeras

A chimera can be produced by fusing cleavage-stage embryos divested of their zona pellucida. Thus by mixing appropriate embryos, chimeras with two, three four or more parents may be produced. Chimeras can also be produced by injecting embryonic cells into the early blastocyst.

Production traits and somatotrophic hormones

It is well recognised that both growth and milk production are significantly lower in buffalo than cattle. Opportunities now exist for improving these traits through somatotrophic hormones

Bovine somatotrophin and milk production

Bovine somatotrophin (ST) or growth hormones (GH) increases milk yield in cows by 10-40%, being higher after than before peak lactation. There is increasing evidence that milk from cows treated with growth hormone is safe for human consumption. Recombinant DNA techniques have made it possible to produce large quantities of somatotrophic hormones, which include growth hormone (GH, somatotrophin), somatotrophin releasing factor (SRF), somatomedin (SF or insulin-like growth factors I and II) and somatostatin (somatotrophin release inhibiting factor, SRIF). As stated earlier, a novel method of increasing somatotrophin secretion is by immunoneutralization of somatostatin.

Growth and carcass quality

Administration of recombinant somatotrophin results in accelerated growth and leaner carcasses in meat animals. Immunomodulation can also be used for enhancing the activity of endogenous anabolic hormones. However, unless the expression of the gene is controlled with promoters, the health status of the transgenic animals is severely impaired.

Rumen biotechnology

Rumen biotechnology has the potential to improve the nutritive value of ruminant feedstuffs that are fibrous, low in nitrogen and of limited nutritional value for other animal species. Knowledge of rumen digestion that is relevant to modifying the nutritive value of feedstuffs and the rumen microbial ecosystem by biotechnology has been reviewed extensively. McSweeney *et al.* (1999) discusses the use and potential of biotechnology to alter the amount and availability of carbohydrate and protein in plants as well as the rate and extent of fermentation and metabolism of these nutrients in the rumen. Current limitations include: isolation and taxonomic identification of strains for inoculation and DNA recombination; isolation and characterisation of candidate enzymes; level of production, localisation and efficiency of secretion of the recombinant enzyme; stability of the introduced gene; fitness, survival and functional contribution of introduced new strains.

Biotechnology and Buffalo Health

Progress has been made in using transgenic animals to increase disease resistance; such an approach may prove useful in reducing the incidence of specific tropical diseases.

Disease diagnosis

Biotechnology is playing an important role in the diagnosis of some viral and bacterial diseases of the buffalo. In the past, diagnosis of most diseases was based on serological tests. The enzyme-linked immunosorbent assay (ELISA), a rapid method of identifying viral and bacterial infections could be employed for the eradication or control of epidemic diseases, which inflict high mortality (Sutherland, 1994). The ELISA could be employed to diagnose and monitor the effectiveness of vaccination programmes such as rinderpest, haemorrhagic septicaemia (HS), and brucellosis.

Synthetic vaccines

In classical vaccine production, (a) the source of the natural antigen can be dangerous and/or impossible to prepare in sufficient amounts, and (b) cross-reaction with host tissues can also occur. Synthetic vaccines have been developed by substituting native antigenic determinants using recombinant DNA technology and genetic engineering. These recombinant vaccines could be used against the major diseases of buffalo such as HS. A vaccinia virus recombinant vaccine against rinderpest overcomes major logistical problems of the tissue culture vaccine. Not only can the vaccine be administered by scarification as in smallpox but also the lyophilised form of the vaccinia virus is heat-stable and does not require refrigeration.

Conclusions and Recommendations

Spectacular results could be achieved by production of transgenic animals and clones leading to a lifetime and heritable expression of their effects in the buffalo. But the desired gene(s) must be identified, isolated and prepared for gene insertion. Traits carrying several advantages could be exploited using these emerging technologies.

Currently, AI, IVF, ET, and sexing and cryopreservation of sperm and embryos for preserving genomes of superior buffaloes in breeding programmes are in progress in many Asian countries, particularly in India. Cloning would not be used in selection programmes but to disseminate genomes from elite herds to the commercial farmer. In this scenario, cloned embryos would be delivered to the farm in the same way as semen straws. Whether cloning of buffaloes will become a reality will be determined by cost/benefit analysis.

Suitable rumen microorganisms naturally selected or genetically engineered could be used to develop new feeding strategies to enhance buffalo production on low quality feeds. Growth promotants and regulators from immuno-manipulation and feed enzymes are strategies to be considered to improve growth rates, leaner carcasses and higher milk yields, and reduce feed costs. Recombinant technologies for vaccine production and improved methods for disease diagnosis and disease surveillance, need serious attention.

Asian countries should launch their own biotechnology research programmes and not depend on the developed nations for new products and research. The use of biotechnology in buffalo research is a costly undertaking that requires long-term commitment of personnel and resources. A substantial increase of funding for basic research to broaden and speed up the process of technology transfer in the buffalo is urgently required.

Progress of biotechnology in buffalo research would be extremely slow without the commitment of national research institutions, and international organisations. Therefore, Asian countries

should seek technical assistance to establish research linkages among institutions engaged in biotechnology within and among countries. The Food and Agriculture Organisation (FAO), the International Atomic Energy Agency (IAEA), and Swedish Agency for Research Cooperation (SAREC) and other international agencies with special expertise should continue to assist member countries in capacity building of research facilities and training of biotechnologists. Biotechnologists should be provided opportunities to attend seminars, workshops and courses on the use of emerging technologies.

While retaining the Asian buffalo's traditional role in the rural farming system, let us emulate the experiences of buffalo rearing in Italy and South Pmerican countries and encourage Asian biotechnologists to apply emerging technologies for the commercial proauction of milk and meat from this sadly neglected animal.

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PLENARY SESSION IV

A Vision for the New Millenium

Discussion

Q. O.P. Dhanda - Inhibin has antigonadotrophic effects. Trials in India have shown that to suppress, Inhibin can be used to induce superovulation. Folliculogenesis in buffaloes needs further study in order to improve superovulation.

A. M.R. Jainudeen - However, with transgenics and cloning, the method of traditional embryo transfer will be superseded.

Q. Bogahawatte - There is a need to consider the economic aspects of biotechnology and to evaluate the costs in relation to the benefits.

A. M. R. Jainudeen - Economics is important. Now with new technologies, the costs of embryos have been reduced. With time, the technologies become cheaper.

Q. M.C.N. Jayasuriya - What about the rural farmer in Asia?

A. M.R. Jainudeen - With biotechnology, it has to be focussed on commercial farmers rather than rural farmers.

Q. S.K. Ranjhan - In India, we have used a lot of biotechnology in many fields and we have spent a lot on money. But, we still have not produced a single useful transgenic organism that produces a substance of value. In Asia, most of the farms are rural farms, not commercial. Hence, what is the role of biotechnology?

A. The rinderpest vaccine that is now being used is a recombinant product. So we should look at the developments in cattle and see what direction buffalo research should follow.

GENETIC IMPROVEMENT OF BUFFALOES IN ASIA WITH SPECIAL REFERENCE TO SRI LANKA

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Abstract: Over 95% of the buffalo population resides in Asia, contributing to more than 96% of global buffalo milk production. About 70% of the water buffalo population belong to riverine breeds, some of which have been genetically improved for dairy characters. River breeds are predominantly distributed in the Indian Sub-continent and Mediterranean countries. Global milk production from buffaloes is increasing partly due to the increase in the buffalo population and improvement of the genetic potential of animals. Some genetic progress has been achieved in a few distinct river buffalo breeds in India and Pakistan through performance recording and progeny testing. With rest of the breeds (swamp and river types), the genetic selection practiced, if any, is through visual observation. In many countries, cross breeding has been the key to genetic improvement and development of multipurpose buffaloes. The extent of artificial insemination (AI) usage in buffaloes is less than 1% in many countries, owing to the difficulty in heat detection in female buffaloes and many other problems associated with AI services in the field.

The indigenous buffalo in Sri Lanka (Lanka buffalo) is a small animal (mature weight being less than 330kg) with a milk yield of about 360 kg in a 250 day lactation period. It is classified as a swamp type, but has a karyotype similar to river breeds. Several consignments of Murrah, Surti and Nili-Ravi buffaloes have been imported to Sri Lanka since 1937 for crossbreeding purposes. Based on a review of crossbreeding studies conducted during the last six decades on buffaloes in Sri Lanka, it can be concluded that there exists a substantial amount of additive and heterosis effects to be exploited through designed crossbreeding programs. The basic upgrading scheme, i.e. the replacement of the local population by continuous mating with improved breeds, demands the availability of a large number of bulls of improved breeds or an extensive AI program, both of which are difficult to be achieved in practice. In order to satisfy the island-wide demand for breeding material, the implementation of a breeding scheme with 3-tiers (nucleus, multiplier and commercial level) is proposed. Several nucleus and multiplier herds can be established according to the demand in different regions of the country using the resources in existing Government livestock farms and private (contract) herds, respectively. Semen or stud bulls of several improved breeds can be used at least at the nucleus level. The open nucleus scheme is recommended, as it is expected to provide the maximum utility (best in terms of rate of genetic gain and risk) compared to closed nucleus and conventional progeny testing schemes. Partial lactation records are suggested to be used for breeding value estimation (using the index selection or preferably BLUP method) to reduce the generation interval and some practical difficulties at field level.

Keywords: Genetic improvement, buffaloes, Asia, Sri Lanka.

Breeding Programmes in Asia

Of the world population of approximately 149 million buffaloes, about 95% are found in Asia and more than 67% reside in South Asia (FAG, 1995). The Asian countries currently contribute to over 96 per cent of the world's buffalo milk production; India, Pakistan, China and Nepal being the largest producers (Ganguli, 1997). Between the two breed types of water buffalo, the river type is the most common, accounting for about 70% of the world population and consisting of some Asian and Mediterranean breeds. The other type (swamp breed) is common in China and Southeast Asia, including Sri Lanka (Chantalakhana and Bunyavejchewin, 1996). The production Yearbook of the FAO (1995) reports a positive growth in milk production in many Asian countries during 1981-1994, which is mostly due to the increase in the buffalo population in those countries. Efforts made on genetic improvement of buffaloes by those countries may also have contributed to this progress. The riverine buffaloes in the Indo-Pakistan Sub-continent are mainly dairy breeds, some of which have been genetically improved by artificial selection for centuries. Among them, the best known are the Murrah, Mehsana and Surti in India (Ganguli, 1997) and

Nili-Ravi and Kundhi in Pakistan (Khan, 1996). Six distinct pure breeds have been recognized by the Indian Council of Agricultural Research. Pure breeding with performance evaluation and progeny testing has been the main objective in the breeding policy of India. However, many buffaloes in India fall into the nondescript category, which require cross breeding for their genetic improvement (Sastry, 1997). The current broad national breeding policy requires detailed delineation to suit for different regions within each state of India. The 8th five-year breeding plan in Pakistan is aimed at increasing productivity of buffaloes instead of population size. The traits defined for improvement are milk and meat production, draught capacity and reproductive efficiency (Malik and Ahmed, 1997). In the rest of the countries in Asia, much of the genetic improvement realized is due to cross breeding. In the Philippines, Carabao (native breed) is being crossed with Murrah and occasionally with Nili-Ravi to produce a stabilized population of crossbreds (with 50% local and 50% exotic blood), which will have draught capacity similar to the native breed, but with much improved milk and meat production (Apelo, 1997). The breeding policy of Nepal focuses on upgrading the local buffaloes (Parkote and Lime) with Murrah to reach 100% exotic blood level (Shrest and Sherchand, 1997). China, Indonesia, Singapore and Burma also have imported Murrah for cross breeding purposes. However, in some countries such as Vietnam, cross breeding programmes with Murrah have been very difficult to implement as farmers rear buffaloes only for draught purposes (Long, 1997). In Malaysia, pure breeding of local swamp buffaloes and Murrah separately was planned to be continued as local buffaloes (98% of the population) are proven to be suitable for draught and meat purposes, while the Murrah is a high milk producer with low potential for draught (Raymond and Ratnakumar, 1997). In implementing any breeding policy, continuous assessments and frequent adjustments must be made by reviewing the policies periodically, based on genetic progress made in the country. Lack of reliable record keeping has been a main problem for monitoring the progress. As many governments in Asia cannot provide all inputs and services for breeding activities of the whole farmer population, Government assistance should be given to form private breeder organizations to take over most of the genetic improvement activities.

Progeny testing in Asia

Successful progeny testing involves recording of performance of individual buffaloes in the field, intense selection of young sires, large-scale artificial insemination, data collection and processing. This has not happened in buffaloes on a meaningful scale in Asia. Large scale progeny testing programmes have not been common on a national scale, but operate at the level of the provincial state in some countries, like with Nili-Ravi buffaloes in Pakistan (Khan, 1996) and with Mehsana and Murrah breeds in India (Trivedi, 1996). Lack of consistent field recording by small-scale farmers in rural areas is a major obstacle. Also the animals used in the progeny testing programme may be culled, sold or have died before completion of lactation. Khan and Iqbal (1996) suggested that use of milk records of the first five months are sufficient to predict the complete lactation yield and to rank progeny testing of sires effectively. Adaptation of this practice should reduce the generation interval and the cost of progeny testing significantly and increase the rate of genetic progress. Statistical modeling of lactation curves for different breeds and regions will also be helpful, as these would enable the geneticists to predict the total lactation yield from whatever intermittent records available.

Genetic improvement for draught power

Although many Asian countries use buffaloes for draught purposes, the basis of selection of parents with superior draught power has been limited mainly to appearance. Performance measuring and recording is virtually nonexistent as far as draught power is concerned. The complexity of measuring procedures of draught power has made it impracticable at the field level. However, in small scale, at least for the few elite breeding buffalo bulls in nucleus schemes or in research herds, draught power should be measured by introducing improved draught power measuring equipments. These equipments must have facilities for calibration and standardization so that the data are comparable across regions and countries. Hence breeding value estimates for

draught bulls can be obtained and comparisons can be made as bull semen is distributed across countries. Developing standard equipment must be a collective effort of animal scientists and agricultural engineers throughout Asia. In fact, effective future research studies on draught power have to be strictly multidisciplinary involving animal scientists, agronomists, soil scientists and engineers (Devendra, 1996).

Multiple trait selection

When genetic improvement for several traits (draught, meat, milk etc.) is required simultaneously, selection of animals should be carried out using an index that combines information on several traits from the animal and its relatives. Unfortunately this procedure is rarely used in buffaloes in Asia. Evaluation of progeny performance (feedback) is essential and significance of the differences in field level performance of pure breeds and crosses should be determined. Ideally statistical adjustments for non-genetic factors such as parity, management (herd effect), lactation length, days dry, days open, calving interval, frequency of milking per day, etc. must be made before estimation of breeding values. As buffaloes show seasonal calving patterns, the effect of season also may be included. However, the significance of these non-genetic factors should be verified before developing adjustment factors for them, as some factors have shown no significance in some studies (Ganguli, 1997). Developing adjustment factors for the significant non-genetic effects requires modelling of lactation curves for different ecological zones of the country. A scrub bull castration programme should be adapted and intensified if this is under operation already; so that unwanted pregnancies from inferior bulls can be minimized under the free-range system.

Molecular genetic approach to genetic improvement

Investigations on the extent of chromosome polymorphisms in riverine and swamp buffaloes and the crossbreds (F_2 generation in particular) and the fertility of crossbreds are among the priorities of current molecular genetic research of buffaloes. Studies on genetic distances and relationships among buffalo populations in different countries in Asia are of great significance in terms of evolution and solving some problems of origin and development of buffalo breeds. A large number of microsatellite markers are available now, which can be applied across species (Devendra, 1996). Masina *et al.* (1997) provides an excellent review on recent developments in molecular genetic methods that helps the breeder to identify individual loci that affect economic traits which can be applied to buffaloes as well. However, the development of molecular markers for selection of buffalo bulls is still at the research level and the operational cost associated with molecular methods of sire selection will be a major hurdle to overcome before employing them effectively at the field level.

Buffalo Production in Sri Lanka

Several estimations of population size of buffaloes in Sri Lanka are available, the widely accepted figure being 843,700, of which about 99 per cent is of indigenous type (de Silva *et al.*, 1985). Indigenous buffalo in Sri Lanka, classified as *Bubalus bubalis bubalis* (Phillips, 1935) is smaller in size than many other buffaloes in the region and seldom exceeds 320 kg in mature weight (FAO, 1977). It has crescentic shaped horns and a variation of coat colours, the commonest being leaden gray (Wijeratne, 1962). It has been categorized as a swamp type phenotypically (Macgregor, 1941), but was found to possess the karyotype of river buffaloes having 50 chromosomes (Bongso *et al.*, 1978), producing no genetic complication when crossing with improved riverine breeds. Hence, the hypothesis is that the Lanka buffalo is a descendent of river type, but later changed phenotypically to assume swamp type characters (Bongso *et al.*, 1978). In addition, there exists a population of wild buffaloes which some scientists (Deraniyagala, 1953-55) classify as a separate sub-species (*Bubalus bubalis miona*).

The water buffalo in Sri Lanka is primarily used for draught purposes, but it is gaining recognition in many areas as a dairy animal. Meat production has not been a declared objective since the ban on slaughtering buffaloes was imposed by the government (Animals Act defined in 1958 and confirmed in 1979) as a step to increase buffalo population. Draught power of buffaloes is utilised mainly for ploughing, harrowing, treading of paddy fields, threshing the harvest and puddling clay for making bricks and tiles. Currently about 36 per cent of the agricultural lands are cultivated using animal power and 95 percent of the buffaloes used, are of the indigenous type (Hulangamuwa, 1998). According to a survey conducted on 16 of the 24 districts covering about 2 per cent of the buffalo population of Sri Lanka, only 2% of the buffalo farmers raise buffaloes solely for dairy purposes. On the contrary, about 64 % of the farmers were shown to keep buffaloes for draught without milking them. The rest (34% of the farmers) managed them for both dairy and draught purposes and sometimes as a source of meat. Over 90% of the buffalo farmers used their animals for land preparation and rice cultivation (Perera and de Silva, 1985; de Silva *et al.*, 1985). According to the above survey, only 13% of the buffalo cow population were milked regularly. Yet about 25% of the milk production of the country are produced by buffaloes (Abeygunawardena and Abeygunawardena, 1998). Milk of the Lanka buffalo was reported to have a fat percentage (7.4 per cent) similar to that of the Murrah buffalo. However the protein content was slightly higher (5.2 per cent) being comparable to that of swamp buffaloes of Philippines and China (Horadagoda, 1990).

Most of the buffaloes in Sri Lanka receive very little attention by the owners not only with regard to breeding, but also to feeding and management. No deliberate selection of adults for future matings is practiced. However, castration of superior males is conducted to enable handling and management of animals and much less to avoid unnecessary mating (de Silva *et al.*, 1985). Unfortunately, the traditional practice of castration of superior bulls has made a negative impact on genetic improvement for draught power throughout the past. As the land available for free grazing is becoming more and more limited, reduction of the number of animals that can be raised is unavoidable. Hence the output per animal and efficiency have to be increased which can be achieved only by improving the genetic potential of the animals and the overall management standards. Shortage of good quality breeding stock is recognized as a major constraint to the development of buffalo farming in Sri Lanka (Subasinghe, 1989).

National level co-ordination

Since 1937, the Sri Lankan Government has introduced several consignments of Indian river buffaloes, particularly the Murrah breed to upgrade the local swamp-type buffaloes (Rajamahendran *et al.*, 1981; Subasinghe, 1989). Currently breeding activities in the country are being carried out by two principal agencies, namely National Livestock Development Board (NLDB) and Livestock Division of the Mahaweli Authority of Sri Lanka. The former is under the purview of the Ministry of Livestock Development Estate Infrastructure and the latter is part of the Ministry of Mahaweli Development (M/RID and GTZ, 1988). It is the responsibility of the NLDB to maintain large farms for crossbreeding purposes of buffaloes (as well as other livestock species and poultry) with improved breeds and issue breeding material to individual farmers. The role of the NLDB in buffalo development is described in Fonseka (1989). Currently a total of over 1700 buffaloes are carried in 11 NLDB farms distributed in all agro-climatological zones in the country. This population consisting of Munah, Nili-Ravi and Surti breeds and crosses concentrated mainly in Ridiyagama, Melsiripura, Nikaweratiya, Haragama, Marandawila and Beligama farms. The Murrah buffalo is the most commonly used improved breed. The Mahaweli Authority plays a role of supplementation to the national breeding programme particularly through upgrading the local buffalo to produce a dual purpose type (milk and draught) by crossing with Surti and Nili Ravi breeds. National level co-ordination is carried out by National Breeding Committee established in 1984 (M/RID and GTZ, 1988). According to the breeding policy outlined by the National Breeding Committee in 1994, grading up of existing buffalo population with pure riverine (exotic) breeds up to 100% level was recommended for intensively managed

farms. For farms following extensive management systems, grading up to 50% exotic blood level followed by *inter-se* mating of the resultant population was recommended (MJAL & F, 1994).

Performance of indigenous and river type buffaloes and their crosses

Many of the studies carried out in the past on performance evaluation of the Lanka buffalo, imported riverine breeds and their crosses were in the form of farmer surveys or based on farm records (Siriwardene *et al.*, 1999). The majority of these studies that were conducted during the last few decades in Sri Lanka are summarized in Table 1.

Table 1. Summary of breeding and performance evaluation research conducted on local and exotic breeds of buffaloes and their crosses in Sri Lanka.

Trait	Local	Murrah	Surti	Nili-Ravi	Murrah Crosses	Reference
Age at puberty (months)	35.6					Abeygunawardena <i>et al</i> (1993)
Age at first calving (months)	46.0	44.3				Abeygunawardena <i>et al.</i> (1980)
	44.9	55.0	51.8	52.1		Abeygunawardena <i>et al</i> (1993)
	44.0					Abeygunawardena <i>et al</i> (1996)
		60.5				Jalatge (1980)
	44.0					Jalatge & Buwanendran (1971)
						Kumaratileke & Buwanendran (1979)
		51.6				Perera (1982)
	45.2					Perera <i>et al</i> (1984)
		50.4				Rajamahendran <i>et al</i> (1981)
					60.5	Ranawana <i>et al.</i> (1992)
		53.6			51.2 ¹	Tilakaratne and Jalatge (1983)
					50.2 ²	
Calving interval (days)		496.3				Abeygunawardena <i>et al</i> (1980)
	506.8					Abeygunawardena <i>et al</i> (1993)
	507.0	510.0	482	491		Abeygunawardena <i>et al</i> (1996)
	720.0					De Silva <i>et al</i> (1982)
		551.4				Jalatge and Buwanendran (1971)
	474.0					Kumaratileke and Buwanendran (1979)
				454		Komori <i>et al</i> (1994)
		530.6				Perera (1982)
	547.5	525.0				Perera <i>et al</i> (1984)
	384.9					Perera <i>et al</i> (1987)
					487.1	Ranawana <i>et al.</i> (1992)
	447.0	498.0			417 ¹	Tilakaratne and Jalatge (1983)
					543 ²	
	432.0					Wijeratne (1962)
Days open				134		Komori <i>et al.</i> (1994)
	80.8					Perera <i>et al.</i> (1983)
	71.5					Perera <i>et al</i> (1987)
First service conception rate (%)	70.9					Perera (1982)
Services per conception	77.7					Perera <i>et al.</i> (1987)
	1.25					Perera (1982)
	1.34					Perera <i>et al.</i> (1983)
	1.40					Perera <i>et al.</i> (1984)
	1.29					Perera <i>et al.</i> (1987)
Oestrus cycle length	21.0					Abeygunawardena <i>et al.</i> (1993)

(days)					
Gestation length		308.7			Jalatge and Buvanendran (1971)
(days)		310			Perera (1982)
	316.9	309.9			Perera <i>et al.</i> (1984)
	316.0				Perera and de Silva (1985a)
Lactation length		287	267	309	Abeygunawardena <i>et al.</i> (1996)
(days)				291	Komori <i>et al.</i> (1994)
	160.0				Kumaratileke and Buvanendran (1979)
	180.0				Pathiraja (1978)
		305			Rajamahendran <i>et al.</i> (1981)
			286		264 Ranawana <i>et al.</i> (1992)
	248.0				Thamotheram (1980)
Milk yield per lactation (litres)		1052	1003	1761	Wijeratne (1962)
				1698	Abeygunawardena <i>et al.</i> (1996)
	355.0	1300			Komori <i>et al.</i> (1994)
	464.0				956' Jalatge (1980)
	360.0				1203 ²
		1333			Kumaratileke and Buvanendran (1979)
					Pathiraja (1978)
					Rajamahendran <i>et al.</i> (1981)
					1064 Ranawana <i>et al.</i> (1992)
			1460		Thamotheram (1980)
	353.0	1427			829' Tilakaratne and Jalatge (1983)
					1096 ²
Calving rate (%)	360.0				Wijeratne (1962)
	59.0				Abeygunawardena <i>et al.</i> (1993)
	57.8				De Silva <i>et al.</i> (1982)
Mortality rate (%)	58.5				Perera <i>et al.</i> (1984)
	6 – 22				De Silva <i>et al.</i> (1982)
	10-40				Kumaratileke and Buvanendran (1979)
Weight at birth (kg)	17.2				Abeygunawardena <i>et al.</i> (1993)
	17.9	27.6	27.1	30.1	Abeygunawardena <i>et al.</i> (1996)
				29.6	Komori <i>et al.</i> (1994)
			20.5		Thamotheram (1980)
Weight at puberty (kg)	186.0				Abeygunawardena <i>et al.</i> (1993)
Mature weight (kg)	255.0				Abeygunawardena <i>et al.</i> (1993)
Pre-pubertal	155.4				Abeygunawardena <i>et al.</i> (1993)
Growth rate (g/day)	160.0	460	250	520	Abeygunawardena <i>et al.</i> (1996)
				465	Komori <i>et al.</i> (1994)
			350		Thamotheram (1980)
	450	390			Tilakaratne (1980)

¹Murrah x Local cross (F₁)²Murrah x (Murrah x Local cross).

Table 1 indicates three important facts. Firstly, it shows that only a handful of research studies have been conducted on performance evaluation of local buffaloes, imported breeds and their crosses. For example, no study has been carried out on performance of Nili-Ravi x Local cross or Surti-Local despite the fact that these crosses are recommended by the National Breeding Policy for extensive management systems island-wide. Secondly, it reveals that performance of indigenous buffalo is far inferior to the imported river breeds and performance levels of the imported breeds under Sri Lankan climate and management are a little less than the breed standards declared by the countries of origin. The latter may be due to the differences in herd

management status and climates between the country of origin and Sri Lanka. Thirdly it gives some evidence that there exists a considerable amount of additive genetic variation and heterosis to be exploited by a suitable cross breeding scheme. It is also noticeable that crossbreds seldom out-perform their imported parent breed in terms of performance of any economic trait. These results indicate that upgrading schemes with exotic breeds can be effective in genetic improvement of local population. However the extent of upgrading that has taken place in Sri Lanka is far less than expected as found by de Silva *et al.* in 1985 (Table 2). Their survey (covering 16 out of 22 districts of Sri Lanka) showed that in some districts, there was not a single farmer to be found owning pure exotic breeds or crossbred buffaloes. The problem has been that although the upgrading approach is very straightforward, it requires imported bulls or semen units in numbers sufficient for the whole country. Currently as few as 0.6% of the buffalo farmers use artificial insemination (de Silva *et al.*, 1985).

Table 2. Distribution of river type and crossbred buffaloes among farmers in sixteen districts of Sri Lanka¹.

District	Farmers owning river type buffaloes (%)	Mean number of animals/farmer	Farmers owning crossbred buffaloes (%)	Mean number of animals/farmer
Trincomalee	4.8	2.0	14.3	1.7
Batticaloa	16.7	2.7	61.1	2.6
Polonnaruwa	14.3	2.0	28.6	2.3
Anuradhapura	9.5	1.3	7.1	1.7
Hambantota	31.8	1.7	9.1	3.5
Ampara	24.0	1.3	44.0	4.6
Gampaha	7.7	1.0	7.7	2.0
Ratnapura	26.1	2.3	21.7	4.8
Kurunegala	2.0	1.0	2.0	1.5
Matara	1.2	2.0	18.2	10.8
Kalutara	31.8	1.9	59.1	2.9
Kandy, Kegalle, Puttalam, Badulla, Matale	0.0	0.0	0.0	0.0

¹ Source: de Silva *et al.*, (1985)

The use of AI even in dairy cattle is limited especially in the Dry Zone of the country, due to many problems associated with the AI service. In addition to the problems that are common to both cattle and buffaloes, poor demonstration of heat signs by female buffaloes (Jellinek and Avenill, 1982) has made the use of AI for genetic improvement of buffaloes almost an impracticable option. However, it is true that there exists a great demand in the country for breeding material (Subasinghe, 1989). The obvious alternative to AI would be to use natural mating with bulls of improved breeds. However, assuming that the number of breedable bulls needed is approximately 1/25th of the breedable buffalo cow population (which is about 144,000 animals), the country might require well over 5700 imported bulls to meet the demand. Also these sires must be scattered all over the country in such a manner that they are readily accessible to the prospective cows in heat. As the demand for superior breeding material cannot be fulfilled solely by the State farms, any proposed breeding program should encourage private sector (individual owners of superior bull herds and informal sellers of bull calves to other farmers) to be involved formally at some stage. These breeding problems demand development of a 3-tier (nucleus, multiplier and commercial) breeding scheme (Figure 1).

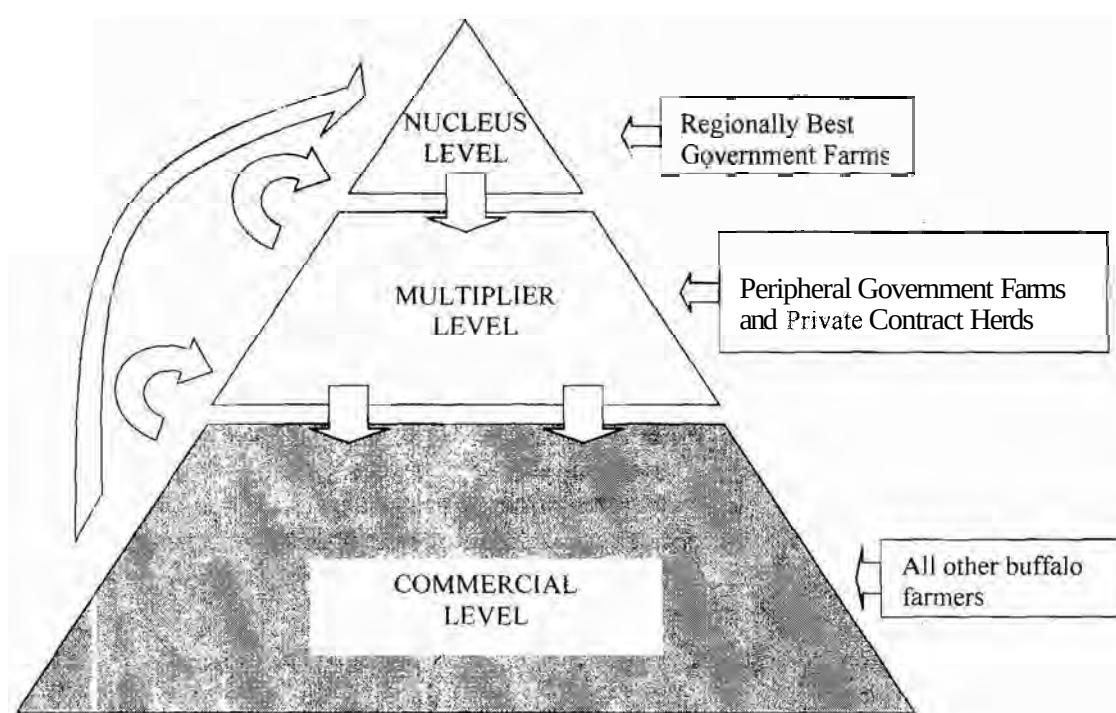


Fig. 1. Proposed multi-tier system of breeding

Establishment of Nucleus and Multiplier Herds

Under a multi-tier system, nucleus herds are the best managed herds (apex of the national population pyramid) consisting of the breeding animals with the highest genetic potential. Initially, these herds can be established with the elite buffalo cows screened from currently available animals in the population. Stud bulls of the herd should come from designated pure riverine breeds (Murrah, Surti and/or Nili-Ravi) with a few best selected from the indigenous population. Inclusion of pure local sires and dams help the comparative evaluation of performance of breeds and crosses. All performance recording (production, reproduction, growth, disease susceptibility, anatomical defects, etc.) and evaluation should be carried out comprehensively at least at this level. In the event that draught power is to be measured, nucleus farms are the best sites to set up all measuring equipment. If AI is used with imported semen to produce the F_1 generation, the identification number of the semen donor must be recorded for future pedigree analysis, progeny testing and across country comparisons. As the appropriate breed combinations may differ, each agro-climatological zone may require one or more separate nucleus herds. When new locations are infeasible, current Government livestock farms established for genetic improvement would be the natural choice of location. Rigorous selection procedures should be carried out among the cows and F_1 females, to determine the occupants of the nucleus for the next year. The multiplier level which receives the F_1 males and all second grade females of the nucleus may occupy other Government farms and/or a selected group of interested private breeders who will eventually be enrolled (registered) in the breeding program. F_1 males from the nucleus can be used for matings at the multiplier level if semen of imported breeds is not adequate. Preferably, performance recording and selection should be carried out at the multiplier level as well. All excess males and females are transferred down to the commercial level (sold to regular farmers at affordable prices for breeding purposes). At the commercial level, scrub bulls must be castrated so that the cows will be bred (even under free-range system) only to the bulls with a higher genetic potential, mainly coming from the multiplier herds. The best offspring in multiplier herds can enter the nucleus (open scheme). Similarly, the very best genetic combinations at the commercial level (that are better than some at multiplier or even nucleus level) can be promoted to those respective herds. Twice a year, all records can be transferred into a central recording station (a

computer lab) where statistical data analysis and genetic evaluations are to be carried out. With the continuous flow of a wealth of information on performance of all pure breeds and crosses available (animals with 50%, 75% exotic blood levels etc.), more and more precise conclusions and recommendations can be made as to which buffalo breed /cross is the most suitable for a given agro-climatological zone. Eventually, the less suitable breeds can be removed from nucleus herds. In situations where the crossbreds have shown better overall performance (in all traits considered) than pure breeds, selection and mating among the crossbreds can be allowed following the path of synthetic breed formation. Although proper nutrition and management facilities should be given to animals to discover their full genetic potential, the conditions should not differ much from the management level expected at the commercial level. This would make it possible to overcome the problem of possible genotype x environment interactions.

National genetic evaluations

Ideally, all of the performance records of animals (milk and fat % of females) in different regions of the country identified with a recognizable identification number (code) must be entered into the computers at the central recording station (centre for genetic evaluations), established in a university or research station), and genetic analysis and prediction of breeding values must be conducted regularly. The genetic evaluations must be conducted at least once a year and information on the best buffalo sires, their locations and predicted performance levels must be made available to the buffalo breeders (and Government Veterinary offices) in the country in the form of a leaflet. When the bull has records available on his relatives as well, that extra information also could be included in the process of estimating breeding values to obtain more accurate estimates. Simply, the Index Selection method can be used to predict breeding values of the buffalo bulls and cows when the non-genetic factors affecting the trait are not significant. However, when several non-genetic factors effect the record of performance of an animal; for example, when adjustments for herd, year, season, age group, parity etc. are required; more accurate statistical procedures, such as Best Linear Unbiased Predictor (BLUP) method (Henderson, 1975) can be used to obtain more reliable and unbiased predictions. Once the required information (performance record, animal identification, sire and dam and information on other non-genetic factors considered) is entered into a central computer (with sufficient processing power), the evaluation program could release the results of the national evaluations promptly. Already many efficient genetic evaluation programs have been developed and widely used in developed countries specially for dairy cattle to produce national genetic evaluations twice a year (Miszta, 1990; Groeneveld *et al.*, 1990). The same programs can be easily adapted for buffaloes in Asia as well, without much alterations. The genetic models such as Sire model, Sire-Maternal Grand Sire model and Animal Model can be used and many programs available today have the capability of incorporating the relationship matrix to estimate breeding values of an animal by considering all available information (performance records of self and/or all of its relatives). If imported semen is used this procedure will provide an estimate of the breeding value of the donor bull living in another country which helps across country comparisons of genotypes. Comparison of performance of the bull's progeny at the country of origin with that in a recipient country will also enable the breeder to estimate the magnitude of influence of non-genetic factors and genotype x environment interaction. Accurate performance recording in the nucleus as well as multiplier level is vital for genetic evaluations. Preferably some incentives must be offered by the Government to the private herds that have registered in the genetic evaluation scheme to encourage accurate and consistent recording on their animals. A technical team can visit the registered farmers regularly to record test-day yields and verify accuracy of recording. As the scheme progresses, recording can be limited to the farmers who have proven to record true information. Initially, standardized partial lactation records of the first five months (Khan and Iqbal, 1996) can be used for genetic evaluations circumventing the problems of lack of complete milk records and long generation interval.

With breeding value predictions made on all candidate animals (sires and dams) on milk production (yield, fat %, etc), reproduction (calving interval, scrotal circumference, etc.), growth

(birth weight, weaning weight, etc.) and draught power of the breedable population, multiple trait selection procedures (Index selection) can be adopted subsequently considering the relative market demand for individual traits.

Risk associated with nucleus herds

Meuwissen (1997) showed that nucleus schemes are associated with higher rates of genetic gains as well as risk than conventional progeny testing schemes. One type of risk associated with nucleus schemes is the danger of introducing diseases and parasites into the nucleus by the animals (carriers) selected from commercial or multiplier levels, occurrence of hidden genetic defects in the animals of nucleus, and the danger of having to depend on a small group of animals for the progress of whole country. Compared to the current situation that is in practice, the expected genetic gain from the proposed scheme far outweighs the relative risk associated. The second type of risk, the type that Meuwissen (1997) discussed, 's the inherently high variance of the selection response associated with the nucleus level (due to low reliability of breeding value estimates) compared with conventional progeny testing schemes. Utility theory is often used to weigh these two aspects, i.e. genetic gain and risk, and utility values are given to different breeding schemes to compare their superiority. The open nucleus scheme suggested by Meuwissen (1997) is supposed to provide a higher utility value than closed nucleus or conventional progeny testing schemes. Thus the breeding scheme proposed here (Figure 1) is expected to provide the maximum utility compared with traditionally established schemes. Reliability (risk) associated with breeding values of animals is a criterion which is as important as the predicted breeding value itself in selecting parents. Dematawewa *et al.* (1995 and 1998) developed a quadratic programming based method to combine breeding values of animals and reliabilities associated with them to select the best set of sires from a pool of sires available to a breeder through natural service or AI. The recommended set gives the maximum guaranteed future income to the farmer. This methodology can be used in importation of buffalo semen, i.e. in deciding the best semen donors from the available set of exotic buffalo bulls and also in recommending the appropriate set of stud bulls for mating at nucleus or or individual breeders at multiplier and commercial levels to obtain the maximum profit.

Summary

It is clear that all Asian countries require a more organized, accurate and widely distributed performance recording system. Based upon the information generated through that system, periodic genetic evaluations of individual buffaloes and comparisons of pure breeds and crosses must be performed. Eventually these results should lead to more accurate selection programmes and formulation of more precise breeding policies for each climatic zone of the country. The need for measurement of draught power and multiple trait selection in the future is emphasized. A multi-tier breeding scheme using the resources of current government and private herds is proposed for Sri Lanka to overcome current breeding problems and meet the demand for breeding materials. The performance recording and evaluation programme discussed here should lead to better breeding policy planning and a higher rate of genetic progress.

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CYTOGENETICS OF INDIGENOUS DOMESTIC BUFFALO IN SRI LANKA: CURRENT STATUS

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Abstract: The buffalo of the species *Bubalus bubalis* has a rare cytogenetic status in that it has two cytotypes differing in their performance, appearance, habitat and global geographical distribution. The river type with a diploid chromosome number of 50 (2n) are dairy animals with jet black skin colour, having short horns which are turned backwards and upwards. They wallow in clear water and are distributed in India, Pakistan, South West Asia and South East Europe. In contrast, the swamp type (2n=48) are draught animals with a dark grey coloured skin having horns growing outwards laterally and horizontally in the same plane of the forehead. They wallow in marshland and are distributed in South East Asia.

Detailed cytogenetic studies using different banding techniques have demonstrated that the reduction of a single pair and the formation of a large submetacentric chromosome of the swamp type has been evolved from a tandem fusion between chromosomes 4 and 9 of the river buffalo karyotype.

The domestic buffalo of Sri Lanka is an exception, in that it is known to have a chromosomal constitution of 50 (2n) though it resembles swamp type in performance, appearance and habitat. The results of a study carried out in 110 animals from different geographical locations confirm the existence of the same chromosomal constitution in indigenous domestic buffaloes in Sri Lanka. In this project, the study of chromosomal morphology was limited to the conventional Geimsa staining technique, but the study clearly revealed the absence of large pair of metacentric chromosome (number 1 of the swamp buffalo karyotype), the marker chromosome of the swamp type. Investigations are required on the cytogenetic status of the feral buffalo and 'true' wild buffaloes (if they do exist) before an authoritative statement could be made on the taxonomy of all indigenous buffaloes of Sri Lanka.

Keywords: Lanka buffalo, cytogenetic status

Introduction

Animal cytogenetics is a study dealing with the application of chromosomal studies on reproduction and diagnosis of some clinical problems. Cytogenetic techniques help in the better understanding of some types of infertility, embryonic and foetal deaths, congenital abnormalities and evolution of species (Wurster and Benirschke, 1968). The water buffalo (*Bubalus bubalis*) represents a rare cytogenetic status as it indicates two cytotypes (i.e. river and swamp types) differing in their chromosomal constitution (Cockrill, 1974). Further, they are different in performance, appearance, habitat and their global distribution (MacGregor, 1941).

The river type has 50 diploid chromosomes (Fisher, 1974) and are mainly dairy animals that prefer clear water in rivers or ponds for wallowing. They are able to thrive on coarse grasses, but will perform better when fed green fodder supplemented with concentrates (Fahimuddin, 1989). The river buffalo is generally massive in size, with a deep chest and relatively larger body. The head is heavy with a prominent forehead and longer face. The shape and size of horns vary considerably according to breed. The most typical types of horns include the curled type in Murrah, sickle shape in Surti, but are never in the same plane as the forehead. The skin colour is black while few appear to be brown due to reddish brown hair. The river buffalo is distributed mainly in India, Pakistan and have also been introduced to Southern Europe, Latin America and Africa.

In contrast, the swamp type with 48 chromosomes (2n=48) are mainly draught animals, that are used in rice cultivation. The swamp buffalo is a barrel shaped, stocky animal with a large girth

and flat forehead. They have wide horns, crescentic in shape, in the same plane as the forehead. The body colour is dark grey with characteristic chevrons in the neck. The swamp type is found in Japan, China and almost all Eastern and South-eastern African countries and in Australia (Cockrill, 1974).

The domestic buffalo in Sri Lanka is an exception in that it is reported to have a diploid chromosome constitution of 50 (Bongso *et al.*, 1977) but resembles the swamp type in performance, appearance and habitat.

Cross breeding of swamp and river buffaloes had been a common practice (Jainudeen, 1983) with the aim of genetic improvement. Numerous reports are available on cytogenetic studies of river x swamp crossbred animals of different generations (Fischer, 1974). Hybrids with a diploid chromosome constitution of 49 are known to be fertile and moreover they have a better productivity. However, due to chromosomal imbalance, problems may occur during segregation leading to reduced fertility. Hence, before large scale cross breeding programmes are undertaken, it is important to study the chromosomal constitution of domestic, feral and wild buffaloes native to Sri Lanka.

Material and Methods

One hundred and ten domestic buffaloes from three provinces (Central, North Central and Southern Provinces) and ten Murrah buffaloes were bled aseptically using heparinized vacutainers. The sample distribution covered eight districts, which account for approximately 50% of the total area of the island. The additional ten samples of Murrah blood were obtained from animals at Central Livestock Research Station, Polonnaruwa.

The blood samples were collected in heparinized vacutainers and transported quickly to the Faculty of Veterinary Medicine for culturing for cytogenetic studies, using the microculture technique (Verma and Babu, 1980). The peripheral blood samples were aseptically cultured for 72 hours at 38°C in 7 ml RPMI media (Gibco), 0.1 ml L-glutamine (Gibco), 1% pokweed mitogen (Gibco) and a penicillin streptomycin preparation (Gibco). Three hours before harvesting, the cells were treated with colcemid (Gibco) in order to arrest the cells in the metaphase. During harvesting, cells were treated with 0.075M KCl. The cell button was fixed with a freshly prepared fixative (methanol: acid = 3:1) and slides were prepared. Unstained slides were examined under phase contrast microscope to select the slides containing good quality metaphase spreads. The air-dried slides were stained for 5 minutes in 5% Geimsa (Merck), rinsed slightly in tap water and mounted in Euquitt. Six slides were prepared from each sample for staining by the Geimsa method. Twenty complete spreads from each sample were studied for chromosome numbers and morphology.

Results

All 110 samples analysed from indigenous buffaloes showed a diploid chromosome number of 50. The ten samples obtained from Murrah animals, the known river type, also contained 50 chromosomes. The large metacentric chromosome which serves as the marker of the swamp type was not observed. Of these 50 chromosomes, the first 4 pairs are distinctly submetacentric while the fifth pair is small and metacentric. The remaining 19 autosomes are acrocentrics. In the female (XX), the largest pair of acrocentrics is sex chromosomes while in the male (XY), the largest and smallest acrocentrics are the X and Y chromosomes respectively.

Discussion

Comparative studies of banding patterns of river and swamp buffaloes indicated that genetic differences have arisen from a balanced tandem fusion between chromosomes 4 (telomere of short arms) and 9 (centromere) of the river type. This tandem fusion leads to the large submetacentric

chromosome number 1 in the swamp karyotype (Di Berardino *et al.*, 1981; Chowdhary *et al.*, 1989) which serves as the marker chromosome.

Samples of indigenous buffaloes collected from different districts indicated the presence of a diploid chromosome number of 50 (2n) without the large submetacentric marker chromosome. This observation is in agreement with that of Bongso *et al.*, 1977 who suggested that indigenous buffaloes in Sri Lanka are of the river type. This hypothesis was further supported by molecular genetic studies carried out in Malaysia on subsamples taken from the same buffaloes used in this study (from the Central, North Central and Southern provinces and samples from purebred Murrah animals) (Barker *et al.*, 1997; Barker *et al.*, 1997; Lau *et al.*, 1998).

These observations confirm that the indigenous domestic buffalo in Sri Lanka genetically resembles river type, whilst in performance, appearance and habitat is of swamp type. Due to this unique status of water buffaloes indigenous in Sri Lanka, they are now referred to as 'Lanka' buffalo (de Silva *et al.*, 1985). However, further investigations are required on the cytogenetic status of the feral buffalo and true wild buffalo (if they exist) before making an authoritative statement on taxonomy of 'Lanka' buffaloes.

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CROSSBRED BUFFALOES: THEIR ADAPTABILITY IN THE DRY ZONE OF SRI LANKA

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Abstract: Approximately 95% of the Lankan buffaloes are found in the dry zone of Sri Lanka and these are used mainly for draught. The breeding policy for Lankan buffaloes is to upgrade them using exotic genotypes such as Murrah or Nili-Ravi. Information on the performance of the F₁ progeny and their suitability for draught purpose is lacking. Therefore one of the objectives of this study was to assess the adaptability of the F₁ progeny in the dry zone,

Rectal temperature, respiratory rate and heart rate were recorded in F₁ animals once a week, in the morning and afternoon for a period of 24 months. Ambient temperature was also recorded twice a day at the time of measurement of physiological parameters. Correlation between ambient temperature and physiological parameters were estimated using computer programs Lotus and SAS. In young animals, there was a highly significant effect of ambient temperature on rectal temperature and respiratory rate indicating a heat stress. But in adult animals the relationship of ambient temperature on rectal temperature and respiratory rate was not significant. In very young animals (age group up to 24m) the respiratory rate was highly dependent on the ambient temperature. The heart rate was not dependent on the ambient temperature.

Daily milk production of the F₁ cows without taking into account the amount consumed by the calf was approximately 1.7 l. The daily average of the Lankan buffalo was approximately 1.4 l. The average lactation length of F₁ cows was 4 mo with a range of 1.5 – 8 mo. There was strong evidence of heat stress in young animals. The simple and effective management techniques to overcome the adverse effect of high ambient temperature should be made available to the farmers. More than half the number of the farmers (51.3%) were not satisfied with the performance of their crossbred animals. Therefore the future of Lankan buffaloes lies in transforming these from a draught type to a dual purpose (milk and draught) or triple purpose (milk, draught and meat) animal.

Although the main objective of buffalo upgrading program is to improve the milk production of the local herds, only 5.7% of farmers reared them for milk. Another small percentage (14.3%) reared them for draught. The majority of them (48.9%) reared buffaloes as dual purpose (milk and draught) while another group (31.0%) used them as triple purpose (milk, draught and meat) animal. It can be concluded that the genetic potential of the crossbred F₁ progeny is not fully exploited in the study area.

Keywords: Crossbred buffaloes, adaptability, performance, dry zone

Introduction

Sri Lanka has a buffalo population of about 825,000 (Sri Lanka Livestock Statistics, 1991-92). Approximately 95% of the population has been categorized as "Lankan" or "Swamp" type buffaloes. The majority of these are found in the dry zone of Sri Lanka, characterized by high ambient temperature (21-38^o C) and humidity (70-85%). The annual rainfall is approximately 1000-1750 mm. There are two drought seasons; February to March and May to October followed by the bimodal rainfall seasons "Yala" and "Maha" respectively. Non availability of sufficient water for buffaloes during the drought periods is a common problem in the Dry zone.

The breeding policy for Lankan buffaloes is to upgrade the existing herds to exotic level (The National Breeding Policy, 1994). Recommended exotic breeds are chiefly the Murrah and Nili-Ravi. The main objective of the crossbreeding program is to improve the milk production potential of Lankan buffaloes by exploiting the effect of heterosis to its maximum. But it should not be forgotten that more than two third (65%) of the buffaloes are owned by small holders and used for fieldwork. According to Gunawardene and Thevamanoharan (1994), buffaloes are primarily reared to work in the fields for rice cultivation and to thresh the grain.

As the exotic breeds have a larger body frame and are sluggish at work, the question whether the upgraded progeny will be suitable for draught purposes is yet, unanswered. In addition to draught power, very little information is available on the growth and production performance of the crossbred buffalo progeny under village management systems. The combined effect of hot and humid weather and scarcity of water prevailing in the tropics may affect the survival and productivity of the buffaloes.

The present study was undertaken to study the adaptability of the F₁ crosses of Murrah X Lankan buffaloes to the high ambient temperature and harsh environmental conditions prevailing in the dry zone.

Materials and Methods

Animals used in this study were chosen from the F₁ generation of Murrah X Lankan buffaloes in two veterinary surgeons' ranges (Galgamuwa and Maho) in the Kumnegala district, where the agroclimatic features are almost similar to those in the dry zone. Thirty-six farmers who owned F₁ cows, which had completed the first lactation, were included in the initial survey. The farmers were identified randomly from the lists provided by the range Veterinarians in the respective areas. Animals were allowed to graze on paddy lands after the harvest, for about 2-2.5 months. During the rest of the period the animals were grazed on natural pastures available in scrub jungles and tank beds. No concentrates were fed to the animals.

For the longitudinal study, animals belonging to thirteen farmers in close vicinity were selected and identified individually using ear tags. The following physiological parameters were recorded of each animal, once a week, morning (0700 hrs), afternoon (1400 hrs) and evening (1800 hrs) for a period of 12 months.

1. Rectal temperature by means of a clinical thermometer (°C)
2. Respiratory rates (breaths/minute)
3. Heart rate (rate of pulse in the caudal vein) beats/minute.

Respiratory rate and heart rate were measured before disturbing the animals. Ambient temperature was also recorded three times a day at the time of measurement of the physiological parameters.

Changes of physiological parameters were measured for both sexes separately. Age of the animals was also recorded. Computer programs, statistical analysis system (SAS) and lotus were used to estimate the correlation between ambient temperature and physiological parameters.

Results and Discussion

The average herd size was 18, within a range of 1-60. Gunawardene and Thevarnanoharan (1994) reported an average herd size of 21 and 29 in the two selected regions included in the study. The herd composition in the study area is shown in Figure 1.

A large number of stud bulls had been distributed among the farmers in the area by a milk collecting company and crossbreeding of Lankan buffaloes was had been in progress for more than two decades. Fifty four percent of the farmers owned stud bulls and used them to serve their own cows as well as the cows of their neighbours.

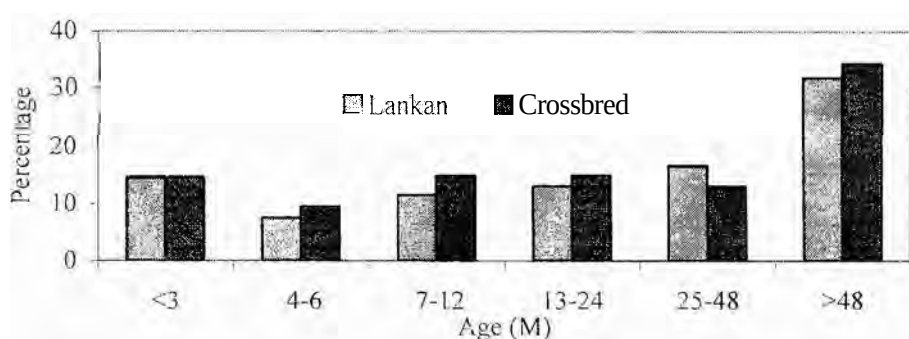


Fig. 1 Herd composition

Out of 360 buffaloes surveyed, 219 (60.8%) were crossbreds. A trend in replacement of Lankan buffaloes with crossbred buffaloes was clearly visible. Therefore the future of the Lankan buffalo lies in transforming the draught animal to a dual purpose (milk and draught) or triple purpose (milk, draught and meat) animal.

Although the phenotypic features of the stud bulls conformed to the breed characteristics, the genotypic characteristics or the selection criteria of the breeding bulls were not known. Fertility of the stud bulls was within the normal range. The average number of services per conception was 2 within a range of 1-5

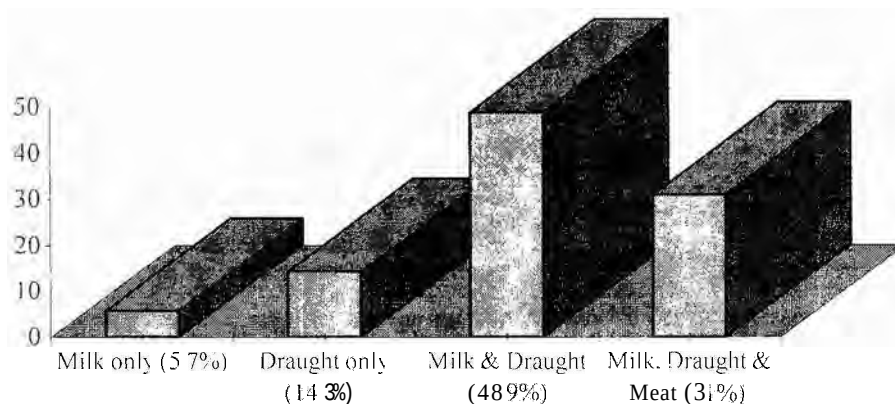


Fig. 2. Purpose for rearing buffaloes

The average daily milk production of F_1 cows was approximately 1.7 litres without taking into account the amount consumed by the calf. The average lactation length of F_1 cows was 4 mo with a range of 1.5-8 mo. The average daily milk production of the Lankan buffaloes in the same area was approximately 1.4 litres, without taking into account the amount consumed by the calf. Average daily milk yield and lactation length of Lankan buffaloes in Kurunegala district reported by Jalathge (1980), were 0.9 lit and 90 days respectively.

Although the main objective of the buffalo upgrading program is to improve the milk production of the local herds, only 5.7% of farmers reared them for milk. Another small percentage (14.3%) reared them for draught. This study revealed that the majority of the farmers (48.9%) reared buffaloes as dual purpose (milk and draught) animals, while another group (31.0%) used them as triple purpose (milk, draught and meat) animals. The purpose of rearing buffaloes in the study area is shown in the Figure 2. This finding was different from that of Gunawardene and Thevamanoharan (1994) According to them the main reason for keeping buffaloes was for

draught. Crossbreeding experiments with Lankan buffaloes have shown great promise in increasing their milk production potential by crossing with the Murrah (Jalathge, 1980). Milk yields of different genotypes of buffaloes are shown in Table 1.

Table 1 Milk yields of different genotypes of buffaloes

Breed	Number of lactations	Yield in litres
Murrah	1282	1317
Indigenous	151	355
1/2 Murrah	368	966
3/4 Murrah	556	1215
7/8 Murrah	112	1249

Source: Jalathge (1980)

Findings of the present study indicated that the milk production and lactation length of F_1 progeny of Murrah X Lankan buffaloes were far below the expected levels. More than half of the farmers (51.3%), were not satisfied with the performance of their crossbred animals.

The buffalo is an animal, which shows a great affinity to water. During the drought period when the supply of adequate water becomes a problem, survival and productivity of buffaloes will be badly affected. Buffaloes are susceptible to deprivation of water even for one day. Ranawana *et al.* (1980) reported a reduction in milk production, when lactating cows were denied wallowing. They further noticed that when drinking water was restricted, the animals were severely stressed and the intake of grass and even rumination was reduced.

Although wallowing facilities were available in the study area during the rainy season, availability of water was restricted during the drought season. Water streams and reservoirs were the common wallowing places for the animals. Tilakaratne *et al.* (1983) confirmed that despite the shade provided, buffaloes suffered from heat stress as the ambient temperature increased from 0700h to 1400h. Lack of wallowing and restriction of water aggravated the stress. Wallowing appears to play a crucial role in adaptation of buffaloes to the tropical environment.

Mean rectal temperature, respiratory rate and heart rate of crossbred buffaloes at 0700, 14 00 and 18 00 hrs are shown in the Table 2.

Rectal temperature, respiratory rate and heart rate showed a progressive increase up to 1400 hr and then gradually decreased with the reduction in the ambient temperature (Figures 3, 4 and 5 respectively). Although the rectal temperature of growing animals is higher than that of adult animals, (Tilakaratne *et al.* 1983) the time affect was highly significant. The relationship between ambient temperature and the three physiological parameters for different age groups of animals is shown in the Table 3. The results indicated that rectal temperature was highly dependent on the ambient temperature. In young animals, there was a highly significant affect of ambient temperature on rectal temperature. But in older animals (> 60m of age), this phenomenon was not observed. There was no significant difference between the sex.

Table 2 Mean rectal temperature, respiration rate and heart rate of crossbred buffaloes at different ambient temperatures.

Time	0700 h	1400 h	1800 h
Mean ambient temperature ($^{\circ}\text{C}$)	27.3	37.2	32.0
Rectal temperature, ($^{\circ}\text{F}$)	100.4	106.1	102.5
Respiratory rate/min.	22.0	95.0	30.0
Heart rate/min.	48.0	52.0	50.0

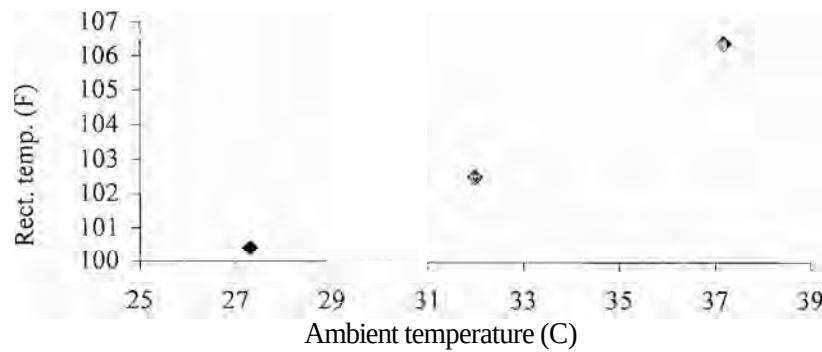


Fig. 3. Effect of ambient temperature on rectal temperature

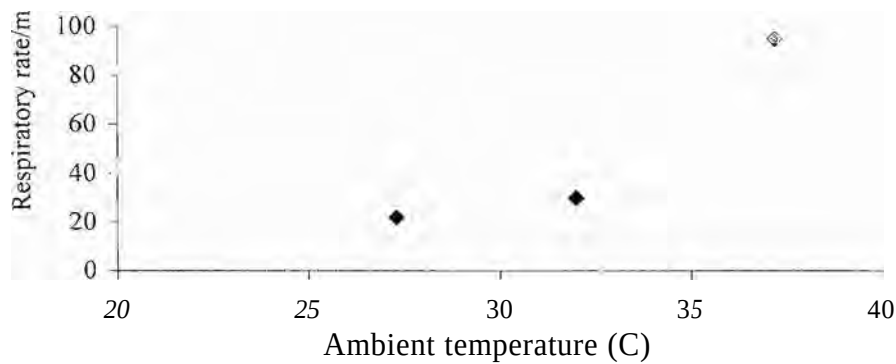


Fig. 4. Effect of ambient temperature on respiratory rate

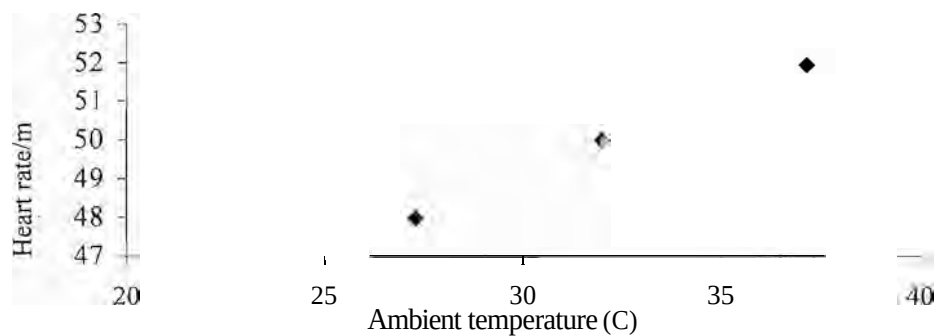


Fig.5. Effect of ambient temperature on heart rate

The same relationship was observed between respiratory rate and ambient temperature. In very young animals (age up to 24 months), respiratory rate was highly dependent on the ambient temperature, indicating a response to heat stress. But in adult animals, the relationship between the ambient temperature and respiratory rate was not significant. Young animals appeared to be dependent more on evaporative heat loss through respiration. This observation is in agreement with the observation made by Tilakaratne *et al.* (1983). The denial of wallowing together with

deprivation of drinking water caused the basal respiratory rate to increase significantly. Heifers had higher respiratory rates than adult animals, at higher temperatures.

Table 3. Relationship (probability >F) between age group and three physiological parameters of crossbred buffaloes.

Age group (m)	Dependent variable		
	Rectal temperature (F ⁰)	Respiratory rate (min.)	Heart rate (min.)
<12	0.0001	0.0001	0.0852
12-24	0.0018	0.0001	0.6928
24-36	0.0001	0.3084	0.0005
36-48	0.0001	0.0001	0.9821
48-60	0.0001	0.7877	0.0513
60-72	0.0723	0.0001	0.4326
>72	0.1965	0.9340	0.0139

Respirative evaporation has greater importance than any other mechanism in maintaining heat balance in buffaloes (Pandey and Roy, 1969). As adult animals develop the capacity to lose moisture through the skin at rates comparable to those of zebu cattle, they are not much affected by high temperature and humidity.

According to the results of this experiment, the heart rate was not dependent on the ambient temperature in any group of animals. But Tilakaratne *et al.* (1983) observed a significantly higher pulse rate in heifers (mean 65.3) compared to the adults (mean 52). Heifers showed a greater elevation at higher ambient temperatures.

Conclusions

A rapid cross breeding process of Lankan buffaloes with exotic genotypes is taking place and the gradual replacement of the Lankan buffaloes in village herds with crossbreds is evident. Although the buffaloes are known to be hardy animals, high ambient temperature and humidity may affect their overall performance. There was strong evidence of heat stress in young animals in the study area. This may affect their growth and subsequent overall production performance. Further research is needed to confirm this. The most critical stage is at calf-hood where strict control measures have to be taken in order, to overcome the adverse effects of high ambient temperature and high humidity. The rise in rectal temperature and respiratory rate in young animals indicated that they are more susceptible to heat stress. Asker *et al.* (1953) concluded that the buffalo calves are more vulnerable to heat stress than adults. It is evident that lactating cows were also affected by high ambient temperature and humidity.

It also can be concluded that the genetic potential of the F₁ progeny was not fully exploited in the study area. The breed improvement program, which had been implemented in an ad-hoc manner, should be re-organized. Bull calves selected and issued for breeding should always be from dams with superior genetic merit. Replacement stock should also be selected from superior cows in the field. The findings of this experiment are in agreement with those observed in other studies carried out elsewhere.

The information gathered, confirms that the stud bulls of exotic genotypes do not suffer from heat stress, indicating that they develop capacities to withstand the adverse effects of unfavorable environments as they grow. Fertility of the bulls was within the normal range.

Training on simple and effective management practices to overcome the adverse effects of high ambient temperatures should be made available to the farmers. Shade is considered to be an important factor in ameliorating climatic stress in buffaloes. But in warmer weather conditions animals will suffer from thermal stress. Provision of sufficient wallowing facilities is another effective management practice to overcome the bad effects of high ambient temperature.

Provision of feeds during the cooler hours of the day, especially during the night is also an important management practice. It has been observed that night feeding of paddy straw has improved the growth rates of buffalo calves and improved the body condition of the adult buffaloes (Chandrasiri, unpublished data).

Acknowledgements

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SYMPOSIUM - I

Genetics and Breeding

Discussion

Q. B.M.A. Oswin Perera - With regard to the different goals how could you organise the multi tier system?

A. C.B.M. Dematawewa - What I suggest is that we need a different nucleus closer to those pockets. Then multipliers around those areas should also be there. There are many people who sell, lease or hand over their bulls to other farmers for stud purposes. Right now nucleus herds are maintained only in Government Farms. Of the breedable cows only 10% are bred through AI's and the balance 90% are bred through natural mating. We cannot locate a nucleus herd in Colombo and ask breeding bulls to be transported to places like Hambantota. Different regions have different agro-climatic and management conditions. There are people who would be willing to do this at a commercial level. They would like to use the resources of the nucleus material, multiply and sell animals. They should also be required to undertake recording etc. We need something like a registration scheme for contract breeders who would have official recognition. The recording systems introduced should be compatible and the information can be incorporated in the data entry forms. We need several of them in different zones according to the demand.

Q. A.K. Misra - You said that Malaysia is going to start nucleus breeding schemes with buffaloes. Do you have a report on this?

A. C.B.M. Dematawewa - No, I don't have a report here. There was a seminar organised by the Ministry of Livestock Development in 1997 at Kandalama, at which delegates presented country papers. The paper from Malaysia indicated that they were intending to start a programme, though not at a national level.

Q S.K. Ranjhan - What is the breeding policy for buffaloes? You have highlighted a genetic strategy to improve the breeding of buffaloes. On paper this looks very good, but looking from a realistic point of view, it is the market forces that determine Government policy. Do you have a single policy or different policies for different regions.

A. C.B. Dematawewa - As far as I understand there are no separate policies for different regions. For buffaloes, Murrah, Nili Ravi and 50% crossbreds are recommended.

Q M.R. Jainudeen - I have seen buffaloes in India that are very similar to the buffaloes in Sri Lanka. Have you looked at these types?

A. P. Abeynayake - No.

. B.M.A. Oswin Perera - With regard to the cytogenetic status of the Indian buffaloes, I have read that they are of the swamp types, that is the karyotype of 48 chromosomes. Is this correct?

A. S.K. Ranjhan - Yes. These types are found in Assam and the Northeastern parts close to Myanmar and Bangladesh.

Q A. Borghese. - It is clear that your interest is on stress and you have monitored the physiology of the animal to show evidence of stress. But in arriving at stress, you need to study the different steps in animal welfare. It is important to monitor the welfare indicators such as metabolic profiles and hormonal profiles before arriving at stress factors. Have you ~~done~~ **any** animal welfare evaluation before stress evaluation?

A. A.D.N. Chandrasiri - No. This study was carried out under field conditions and it **was not** possible to move from farm to farm to do such studies. Future studies should focus on these areas.

Q. K.C. Somapala - What type of animals were used in the study?

A. A.D.N. Chandrasiri - These were first generation Lankan x Murrah crosses.

Q. K.C. Somapala - Are you sure that the Murrah bulls were pure breds?

A. A.D.N. Chandrasiri - Yes. They were from Government Farms and phenotypically they were pure breds.

Q B.M.A. Oswin Perera - Was there any information on the performance of the dams of the bulls that were used?

A. A.D.N. Chandrasiri - All the bulls born in the farm had been issued. It was not possible to obtain this information from the records.

Q. K.C. Somapala - Do we have any reports of studies to show whether cross breeding has been effective?

A. A.D.N. Chandrasiri - The studies done by Dr. Jalatge show that milk production increased gradually with increase in Murrah blood. But this was not seen clearly in the study area. This is why I mentioned that the genetic potential of the Murrah has not been fully exploited. This may be due to the sire factor and also the climatic and management conditions.

TECHNOLOGIES FOR IMPROVING BUFFALO NUTRITION IN THE NEW MILLENNIUM: TRENDS AND PROSPECTS

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Abstract: Statistics clearly show that the world buffalo population has increased during the past 15 years. This has occurred despite the fact that the new innovations during the period, relating to the treatment of fibrous crop residues and supplementation strategies involving the use of small amounts of soluble and rumen non-degradable nutrients, have had no significant impact on production. The water buffalo, especially at the small farmer level, will continue to depend on poor quality forages, crop residues and agro-industrial by-products for their nutrient supply. Large inputs of alternative feedstuffs are not possible due to the low availability of such feeds as well as to economic constraints. The strategy would therefore be to add low levels of supplements to existing basal feeds, to promote modest increases in production. This low-level supplementation approach will provide limiting nutrients to the microorganisms and improve the efficiency of rumen microbial function. It would allow the rumen to reach its potential production level, and the resulting increase in the microbial bio-mass will in turn increase feed intake and production of the animal.

The knowledge of the microbial contribution to the nutrition of the host animal is essential when developing feed supplementation strategies, for improving ruminant production. While this has been well recognized for many years, it has been extremely difficult to determine the microbial protein contribution to ruminant nutrition. Surgically modified animals and marker techniques have been used to estimate the digesta outflow and the rate of production of microbial protein. However, recently the Purine Nitrogen Index (PNI), a new parameter which has a potential for assessing the efficiency of conversion of dietary nitrogen to microbial protein, has been proposed as a means of establishing the nutritional adequacy in ruminant livestock. Technologies directed towards the manipulation of the rumen ecosystem by way of microbial or anti-microbial feed additives, the removal of protozoa and genetic manipulation of ruminal microorganisms may have prospects for the future. What may prove more difficult could be the maintenance of new strains in the mixed ruminal populations.

Livestock development in most developing countries is constrained by minimal public sector investment and participation, and inefficient and often poorly coordinated support services. A number of macro economic policies involving pricing of raw materials and products, producer and consumer subsidies, infrastructure development for storage, processing, marketing and research and extension services have both direct and indirect impacts on livestock production.

Keywords: Nutrition, future trends, prospects, purine nitrogen index, nitrogen conversion efficiency.

Introduction

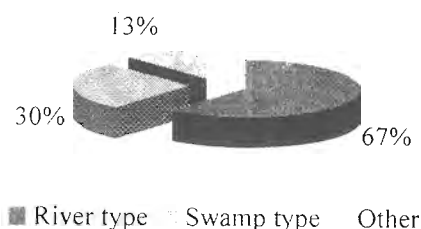
The world population of water buffaloes has reached 152 million according to statistics compiled at the FAO (FAO, 1998). Nearly 96% of this buffalo population are located in Asia; India having the largest buffalo population of 53% of the world total. China and Pakistan come second and third with 15 and 13%, respectively (Table 1). These statistics clearly show that the world buffalo population has increased over the 15 year period 1981-1996 by over 30 million (an average annual increase of nearly 2 million), disputing the view that the world buffalo population has been dwindling.

Domestic buffaloes are divided into two main types. Over 65% of the domestic buffaloes are of the river type and around 30% are of the swamp type. The rest mostly being the Mediterranean type (Figure 1). While the river type has been developed by selection for milk production (India, Pakistan), the swamp type is primarily the work animal of rice growing countries such as China, Thailand, Philippines, Vietnam and Indonesia.

Table 1. World buffalo population – 1996

Region/Country	1979-81	1991	1996
	(Million head)		
Asia	118.08	141.99	147.26
India	66.08	78.96	80.10
China	18.27	21.71	22.81
Cambodia	0.37	0.75	0.77
Pakistan	11.59	17.82	20.20
Thailand	5.93	4.97	4.81
Indonesia	2.45	3.33	3.14
Nepal	2.40	3.04	3.30
Vietnam	2.31	2.85	3.01
Philippines	2.84	2.64	2.84
Myanmar	1.89	2.10	2.26
Laos	0.83	1.09	1.20
Sri Lanka	0.86	0.82	0.76
Malaysia	0.27	0.20	0.16
Europe	0.44	0.34	-
World total	121.74	147.18	151.96

Source: FAO, 1998

**Fig 1.** Different buffalo types in the world

The Role and Contribution of Ruminant Livestock towards Global Food Needs

Livestock in general are an important component of traditional agriculture, complementing arable cropping in most developing countries. Their contribution to the economic welfare of the people extends beyond the traditional uses of supplying meat and milk. Livestock are multipurpose animals. In addition to their importance for meat and milk they are valued for their hides, skin, fuel and fertilizer. They provide manure, which helps to replenish soil fertility by restoring nutrients that crops utilize. In many societies (e.g. India and Bangladesh), animal manure is used as a fuel for cooking purposes. For many rural smallholder farmers, livestock are a 'living bank' and serve as a financial reserve for periods of economic distress and crop failure. They are a primary source of cash income for farmers to buy grain and other food items. They enable the farmers to purchase agricultural inputs such as seed, fertilizer and other requirements. On average, livestock accounts for half of agricultural output when both their direct and indirect contributions are considered. Directly, they provide food (meat and milk) and non-food products (hides and skins) amounting to about 20% of agricultural domestic product. Indirectly, they contribute over 30% by supplying essential inputs to agricultural production. In mixed crop-livestock farming systems, livestock also have a critical role to play in the development of sustainable and environmentally sound production systems. In addition to their direct contribution to the sustainability of farming systems by providing manure, livestock increase productivity of

marginally productive land that may be vulnerable to degradation. Legumes grown to feed livestock also provide nitrogen for crop production through fixation of atmospheric nitrogen.

To the crop farmer, especially in Asia, cattle and buffaloes are the primary source of traction and power for ploughing, hauling, pumping, transport and threshing, increasing productivity of small holdings. Domestic buffaloes in all developing countries form an integral part of farming systems and have a multi-purpose role in agriculture. In India, Pakistan and Europe buffaloes are kept for milk production. About 70% of milk consumed in India and Pakistan come from buffaloes. The swamp buffalo indigenous to Thailand, Malaysia, Philippines and Indonesia contribute a significant proportion of meat consumed in these countries. In countries such as Sri Lanka, Burma and Vietnam, they are kept mainly for draught purposes and in some instances for their value added products such as curd, ghee and butter.

This keynote address is concerned with the importance of nutrition in buffalo production and the identification of technologies for the 21st century for improving productivity, given the fact that resources are likely to be limited and perhaps remain unchanged.

Constraints to Buffalo Production and Challenges for Improvement in Developing Countries

Feed resources and their utilization – past trends

The major nutritional constraints affecting buffalo production have not changed over the years. Over 15 years ago, Mahadevan (1983) highlighted two major nutritional constraints to buffalo production in Asia. He pointed out that *poor digestibility associated with low intake* as well as the *low availability of dietary nitrogen* were major constraints to buffalo production, especially in the Asian region. The feed resource base of the buffalo is traditionally poor in quality and comes from the uncultivated lands, roadside grazing, crop residues and agro-industrial by-products. The latter is actually the major feed resource supplying the nutrients in most situations. Inevitably these are poor in quality, lack most of the required nutrients, especially of proteins and minerals and are bulky to be transported.

The type of systems adopted in buffalo production has not changed over the past 15 years. The smallholder farmers rearing swamp buffaloes still allow the animals to graze available forage during the day, herd, tether or confine them at night, to keep them away from predators or to ensure that they do not damage crop fields. Some farmers give rice straw as a night feed or in very rare occasions a little concentrate as a supplement. There is rarely any organized production, especially amongst the smallholder farmers. Organized production is seen only in situations where buffaloes are reared on a commercial scale, for milk and meat production (e.g. India, Pakistan).

Mahadevan (1983) also described the attempts that were being made to improve the nutrition of buffalo, especially in the Asian region. The greatest concentration of nutritional research at that time was on methods of treating fibrous crop residues so as to improve their digestibility and nutritive value. Chemical treatment, involving caustic soda, ammonia generated from urea and other methods were being tested with varying degrees of success. Something close to a 'residue revolution' took place in the developing tropics in the 1980s. There was an increase in knowledge on the subject widely publicized through scientific journals, newsletters and other media. However, the results have not had any major impact on buffalo production (or ruminant production in general) under traditional management conditions. Nor is there any evidence to show that the large research effort has resulted in the greater utilization of crop residues and agro-industrial by-products in developing countries (Owen and Jayasuriya, 1989).

At about the same time, there was a resurgence of interest in the use of untreated straw as a basal feed for cattle and buffaloes. Adopting the principles of nutrition, which require that rumen

microbes should be treated separately from the host animal, supplementing strategies were conceived and developed. This necessitated the need for separate consideration of the nutrition of the microbes from the host animal *vis a vis* the nutrition of the microbes and nutrition of the host animal. The development of the urea molasses multivitamin blocks (UMMB) was an outcome of this concept. Attempts were made to satisfy the demand for nutrients of the rumen microorganisms by way of readily available and soluble nitrogen and energy, and supplying the host animal with adequate nutrients, through the provision of 'by-pass nutrients'. Many research projects funded by UN organizations (FAO, IAEA) or other NGOs/bilateral agencies (ILRI, GTZ) were in operation. For example, an IAEA/UNDP project involving the use of UMMB, through utilisation of research findings of national institutes and the application of nutritional principles, achieved remarkable results by improving production and reproduction both in cattle and buffaloes in Indonesia. A similar project funded by the FAO/UNDP was also operational in the Philippines. However, the evidence of the application of UMMB on a wider scale (other than in Indonesia) benefiting the livestock industry in general and buffalo production in particular, is yet to be seen.

The factors responsible for low farmer uptake of new technologies, especially the straw treatment methodology, were highlighted by Owen and Jayasuriya (1989). These factors were identified as: (a) the absence of detailed production patterns of crop residues within countries, including when and where residues are produced, (b) the difficulties in transporting and storing residues, (c) technologies being inappropriate, (d) the near absence of agricultural extension services and (e) the insufficiency of on-farm research to demonstrate the economic benefits that could be derived from the new technologies. However, it was never considered that the use of incorrect target adopter groups could have been a major reason for the low uptake of the new technologies. A smallholder farmer who keeps two milking cows or milch buffaloes as a supplementary source of income, will rarely attempt to increase the output from his animals by adopting new technologies, since the additional income that he may derive would be marginal, in relation to his main income, from say, rice cultivation or cash crop production. If the technology was directed towards a commercially oriented farmer, whose main income was from milk or meat production, then the new technology could have brought him an increased income and therefore the adoption of the new technology would have been a profitable venture. The extra income derived from the new technology should be clear and sufficiently large to warrant the extra effort required, in terms of labour, time and capital. Even a successful farmer-plot demonstration may not change the attitude of a smallholder farmer, unless the extra income derived could justify his efforts.

Feed resources and their utilization – future prospects

Globally, food production seems to have increased during the past few decades, but the productivity of the agricultural sector in many developing countries has been declining. Thus many countries have been importing increasing amounts of food from developed countries, particularly products of animal origin, in order to meet the increasing demand. Urbanization and income growth, changes in food consumption patterns, often lead to the general increase in the consumption of livestock products. The low consumption of animal products in developing countries amongst the rural poor is because of their inability to afford expensive animal products in their diets. They are often vegetarians through necessity rather than by choice. The excessive consumption of animal products is considered to be a serious health hazard primarily in affluent societies and is related to urban life styles. In developing countries, animal fat provides a valuable contribution to the daily energy needs of the people.

The two primary sources of production increase can be envisaged for the future. These are: (a) through an *increase in the number of animals*, either through the expansion in the absolute livestock population or by increasing the off-take rate (for meat production), and (b) *by increasing animal productivity*, which will increase the output of milk and meat per animal, through improved management, feeding, breeding, health and husbandry technologies.

The first trend is expected to prevail in extensive production systems where there is little or no limitations to grazing management (as in many countries in Africa and Latin America). The same applies to countries that have grazing systems with limited scope for expansion but have large areas that are less densely populated (China, Mongolia, Indonesia). The second trend will prevail in many developing countries that lack potential for expansion of their grazing system. They need to increase yields per animal as an important source of growth. Thus, commercial scale production with improved technologies will have to come into operation since only economies of scale will prevail in open and free market oriented economies.

Feed will continue to be a major limiting factor to the expansion of the livestock sector in most developing countries. Therefore, attempts to increase livestock productivity will become more demand driven, capital intensive and high technology oriented. Such production systems will be applicable only to sectors producing poultry meat, pork and eggs. Future development in the ruminant industry will continue to focus on adaptation of technologies that will increase the efficiency of utilization of locally available feed resources and management strategies.

Present trends in buffalo production clearly show that there will be no new feed base for improving productivity in the developing countries in the near future. Production will have to come from existing resources such as cereal straws, poor quality grazing and other agro-industrial by-products with minimum of supplementation. Malaysia has made many attempts to promote the use of oil palm by-products as the main source of nutrients for both cattle and buffalo production. There are reports that in Guatemala, a large commercial milking herd of buffaloes is maintained only on African palm fruit waste and available pasture. Many developing countries in Asia maintain their buffalo herds on poor quality grazing and little or no supplementation.

Technologies for the New Millennium

Urine purine derivative technique for measuring the efficiency of microbial protein production in the rumen

Animals in tropical countries, especially at the smallholder level, will continue to depend on poor quality forages, crop residues and agro-industrial by-products as their major source of nutrients. Large inputs of alternative feedstuffs are not usually possible due to low availability of such feeds as well as due to economic constraints. The strategy would therefore be to add low levels of supplements to result in modest weight gains and increased milk production. The low-level supplementation approach will provide limiting nutrients to the rumen to improve the efficiency of microbial function and thereby allow the rumen to reach its potential production level. The increased production of microbial bio-mass will in turn increase intake and thereby production by the animal. As stated earlier, the supply of nutrients to microbes will maximize the production and efficiency of microbial protein production but a simple and reliable method for determining the extent to which this has been achieved has not been available. Surgically modified animals and marker techniques have been used to estimate the digesta out flow and the rate of production of microbial protein. However, recently a new method for quantifying microbial protein production based on the measurement of the purine derivative excreted in urine, has been developed.

The principle behind this methodology is as follows: Microorganisms have high concentrations of purine containing compounds relative to concentrations in plant and mammalian cells. Moreover, purines in dietary and endogenous materials are in general rapidly degraded by microbial enzymes in the rumen. They are likely to be present in only negligible concentrations in digesta leaving the rumen. The microbial purine on the other hand, remain intact in living microbial cells and pass *via* the abomasum to the small intestine. The purine present in digesta entering the small intestine can therefore be expected to be almost totally of microbial origin. Microbial purines are therefore specific markers of the microbial fraction. If the concentration of purines in the whole digesta and in a pure sample of microbial biomass are expressed as a ratio, the result is an estimate of the

fraction of the digesta that is of microbial origin. If the digesta flow is determined using cannulated animals and non-absorbable gut markers as mentioned above, the flow rate of crude protein or any other microbial component in the digesta can also be determined from its ratio relative to the purine concentration.

Of the microbial purines that are degraded enzymatically to nucleotides and purine bases, some are absorbed into the animal body, but the majority is excreted *via* the kidney in the urine. The rate of excretion of purine derivatives in the urine tend to closely reflect and can therefore be used to predict the flow of microbial purines into the intestine. If the concentration of purines in a pure sample of the mixed microbial biomass, as well as the predicted flow rate of purines from the rumen are known, then the flow of microbial biomass can be simply determined.

Using this principle a potentially new parameter called the Purine Nitrogen Index (PNI) has recently been introduced by Chen and Jayasuriya (1998), for the evaluation of ruminant feeds. The principle of the concept is that during microbial fermentation, part of the dietary nitrogen is converted to ammonia, a proportion of which is captured by the rumen microorganisms for the synthesis of microbial protein. The remaining ammonia is absorbed from the rumen and is finally excreted, as nitrogen, in the urine.

If a diet has a high nitrogen conversion efficiency (NCE), more microbial protein is produced and less nitrogen is excreted in the urine. Therefore, the ratio of intestinal flow of microbial protein nitrogen (MPN) to urinary nitrogen excretion (MPN:UN) will be higher. Conversely, if a diet has a poor nitrogen conversion efficiency, less microbial protein is produced and more nitrogen excreted is in the urine. The MPN:UN ratio will be lower. With the assumption that other factors (e.g. food intake, protein degradability) remain unchanged, it is expected that the MPN:UN ratio is positively correlated to NCE.

Since estimates of microbial protein nitrogen based on purine derivative excretion have been shown to be in close agreement with direct measurements using microbial markers, one could replace the term MPN in the expression MPN:UN with purine derivative nitrogen (PDN). Thus, PDN:UN, i.e. purine derivative nitrogen as a proportion of total nitrogen in the urine, should also be correlated with NCE. This ratio is called the purine nitrogen index or PNI.

Experimental data available from a number of previous studies with sheep were used to test this hypothesis and show the relationship of PNI to NCE. While PNI was calculated as explained above, NCE was calculated as the intestinal flow of microbial nitrogen (g/day) expressed as a proportion of rumen degradable nitrogen (RDN) intake. Pooled data from the experiments showed that PNI was positively correlated with NCE (Figure 2).

A practical application of the concept would be to set an empirical threshold for a specific group of animals, and diets with PNI values lower than this threshold are graded as unsatisfactory with respect to nitrogen utilization. For example, based on the above data a diet with PNI lower than 0.08 for sheep (Figure 2) would seem unsatisfactory. Since PNI is used as a semi-quantitative parameter, its application would not be affected by the 20% variability that is common when spot samples are used in the measurement of purine derivatives in the urine. Therefore, notwithstanding the said limitations, one could use spot samples of urine to measure purine derivatives and thereby use the PNI as a means of formulating ruminant diets that are biologically more efficient and produce less nitrogen waste. The limitations of PNI are: i) the index does not offer any explanation as to the cause of poor efficiency, ii) it is not sensitive enough to detect small differences. Therefore, it could ideally be used in a 'grouping' system. However, because of its potential value, the concept of PNI should be further evaluated and developed in the future. This in fact is a major task of the on-going FAO/IAEA Coordinated Research Programme on "Nuclear based technologies for estimating microbial protein supply in ruminant livestock"

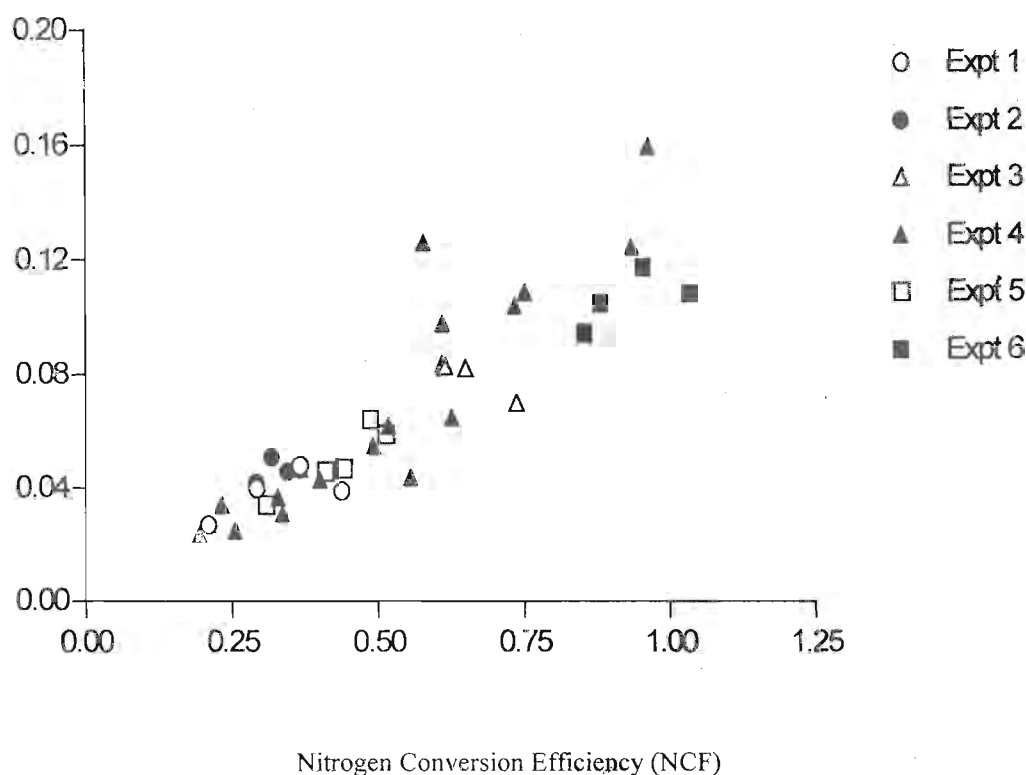


Fig. 2. Pooled data from six experiments showing the relationship of PNI to NCE.

Manipulation of the rumen ecosystem

Use of microbial and anti-microbial feed additives

Over 50 years ago, Hungate (1950) demonstrated for the first time that anaerobic bacteria in the rumen could be cultivated in an exclusively anaerobic environment. This important finding opened up an entirely new area of rumen microbiology, whereby today we talk of the manipulation of the rumen ecosystem involving microbial biotechnologies such as the use of dietary ionophores, antibiotics and microbial feed additives.

Inclusion of dietary ionophores (e.g. monensin) and antibiotics have proven to be economically beneficial in terms of improved feed efficiency. Ionophores change the fermentation stoichiometry and improve the protein flow from the rumen. However, their action, whether it is due to antifungal rather than antibacterial effects or whether their benefits stem from their effects in the rumen or whether they are of post ruminal origin are still not very clear (Wallace, 1994).

Live microbial cultures as feed additives appear to have benefited ruminant nutrition in terms of live weight gain and milk production, by increasing feed intake rather than feed efficiency as in the case of ionophores. They most probably increase the count of anaerobic bacteria (cellulolytic) leading to increased fibre digestion. This latter property may lead to the development of additives suitable for different dietary circumstances.

Removal of ciliates by defaunation

Studies of Coleman (1975) and of Weller and Pilgrim (1974) were the first to indicate that the presence of protozoa in the rumen could be detrimental to ruminant production. It was shown that protozoa consumed bacteria and the protozoa were preferentially retained in the rumen. Therefore, the presence of protozoa were seen to lower the net microbial efficiency in the rumen and in turn lower the availability of bacterial protein to the animal, reducing the protein:energy ratio in the nutrient's absorbed. Only about 30% of the protozoa produced in the rumen appear to leave the rumen.

There has been intensified research during the past decades on the effects of rumen manipulation, especially in relation to the removal of protozoa from the rumen (Nolan *et al.*, 1988). After reviewing recent literature on the implications of protozoa and fungi in the protein nutrition of ruminants, Nolan (1988) reported that in general, the elimination of protozoa increases the rate of flow of microbial protein from the rumen. This is a consequence of an increase in the bacterial biomass and a greater flow of bacteria from the rumen. Rumen digestion of organic matter (OM) may also be higher with all-forage diets but lower with mixed forage/concentrate diets because of the lower rumen digestibility of the fibrous portion of these diets. He concluded that irrespective of the digestibility of OM in the rumen, the overall effect of eliminating fauna is usually a higher efficiency of net microbial synthesis and a higher flow of protein from the rumen, promoting a higher protein:energy ratio in the absorbed nutrients. This often leads to higher levels of animal production, when essential amino acids are the primary limiting nutrients.

Reviewing production responses associated with the absence of ciliate protozoa from the rumen of cattle and sheep, Bird (1988) showed that in general defaunation resulted in significant increases in live weight gain in cattle and wool production in sheep, although results have not always been consistent. He concluded that the final outcome of defaunation is largely determined by the dietary regime and the physiological status of the animal. Available literature on the effects of defaunation on rumen function as well as on production are mainly on cattle and sheep; little or no information is available on the effects of defaunation on the buffalo.

Role of fungi

Anaerobic rumen fungi were first discovered in the rumen of sheep in 1975 but their importance was not immediately recognized. The importance and their possible role in fibre digestion was later recognized, when large populations of fungi were observed to preferentially colonize fibrous plant materials in the rumen of cattle and buffaloes. The attachment, invasion, colonization and digestion of various plant materials by anaerobic rumen fungi have been well described by Ho *et al.* (1988; 1991; 1996).

The nutritional requirements of rumen fungi have not been well defined. However, it is known that the diet of the host animal exerts a significant influence on the population densities of rumen fungi. Provided other nutritional requirements are satisfied, the higher the fibre content of the diet, the higher would be the rumen fungal population. During growth on plant tissues, rumen fungi release a significant quantity of lignin from the tissues. With wheat straw for example, 16-20% of the lignin is lost within 4 days of incubation with rumen fungi.

The attachment of rumen fungi on plant tissue results in a decrease in the tensile strength of the tissues. This weakening will allow greater bacterial fermentation, especially with the aid of rumination. Removal of rumen ciliates by defaunation initially depletes the fungal population but eventually results in a stable and higher population density. A possible beneficial effect of rumen fungi in addition to above could be the synthesis of choline that is required by the host animal. The outcome of the breakdown of fungal cells is not very clear; whether it is completely broken down in the rumen, attributing little nutrition to the animal or whether at least part of it is

available in the abomasum as a source of post-rumen nutrients, especially nitrogen (25-30% on a DM basis) has not been well established.

Studies conducted at UPM in Malaysia by Ho *et al.* (1988) have shown that anaerobic fungi produce a range of polysaccharide degrading enzymes such as cellulases, hemicellulases and xylanases, which break down plant structural materials.

Gene manipulation

Development of successful methods for inserting foreign or modified genes into ruminal microorganisms and ensuring their efficient expression will lead to genetically engineered ruminal microorganisms for the future. If these genetically engineered microorganisms are to be used for nutritional purposes, three scientific objectives must be met. The first is to insert new gene material into ruminal species and ensure that it is expressed, the second is to select a gene product or products that will benefit the nutrition of the host animal and the third is to establish a means by which the new organisms can survive. Apart from these, there are ethical aspects and regulatory constraints which are complex and need careful thought.

Since the first report of the successful cloning of cellulases from *Fibrobacter succinogenes* into *E. coli* by Crosby *et al.* (1984), there have been many reports of genes being cloned from ruminal microorganisms into other expression systems (Wallace, 1994). Similarly, the expression of foreign DNA in ruminal microorganisms has been progressing rapidly since 1988. Much development remains to be done but prospects for achieving the objective of producing genetically engineered ruminal microorganisms are excellent. Details on these aspects are beyond the scope of this presentation and therefore will not be discussed. The situation that may prove more difficult to overcome could be the maintenance of the genetically modified strains in the mixed ruminal populations because factors governing the survival of new strains *in vivo* are not well understood. One could argue that if modified organisms were to benefit both themselves and the host, it would already have evolved. However, the successful introduction of the rumen bacteria that degrades 3 hydroxy-4 (1H)-pyridone (DHP) into Australian ruminants (rumen microorganisms that enable ruminants to use *Leucaena leucocephala*) should be a good example of what is achievable given the limitations.

Conclusions

A major reason why livestock production in general and buffalo production in particular, has not increased significantly over the past decade, is the inability of such systems to respond quickly to increase in demand. The present trend in the increase in monogastric meat production is in line with the observed shift towards urbanization and the consumer oriented market. The lack of a guaranteed and remunerative market for the main commodity, lack of infrastructure, insufficient marketing facilities and open economic policies of many developing countries allowing the importation of value added products at low cost have affected the ruminant livestock sector and consequently limited their production to low and subsistence levels.

The growth potential for extensive grazing and or forage production are limited in most developing countries. In response to increasing population pressure, good pasture land is being converted to crop land for cash crop production, leaving increasingly poor land for grazing and mixed farming operations. Therefore, industrial production of pig and poultry will increase relative to production from grazing land.

The introduction of new innovations to smallholder farmers, even if they are 'appropriate', is one of the most difficult tasks of research and extension personnel. A technology that has been successful in one developing country may not necessarily succeed in another. Many smallholder farmers who rear livestock for supplementary income will be reluctant to change their traditional practices, especially when the new innovations call for extra time, money and labour. The

methods may be too demanding in relation to benefits produced. Most of them would see livestock production as 'a lull period exercise' which may bring in 'some extra income' with little effort. The more likely application of the new technologies would perhaps be with large-scale operations where benefits are clearer and sufficiently large to warrant the extra efforts.

After a thorough examination of the type of support which has been given to buffalo research and development in Asia through international and bilateral funding agencies, Perera (1991) concluded that international support for buffalo research over the past two decades has resulted in substantial strengthening of national institutes both materially and intellectually. The support provided led to infrastructure development, research activities and the promotion of information exchange. However, it was evident that the research results had not contributed adequately towards improving production at the small farmer level in the villages. He suggested that lack of understanding of the problem, from the farmer's point of view for tackling problems involving actual farming situations, because such projects are difficult to execute and may not provide publishable data and lack of contact of scientists working in universities and research institutions with extension and field services, were some of the reasons for poor adoption of research results. It is my view that in addition to all these, existing subsistence farming systems need to shift to commercialization if new technologies are to benefit the farming communities.

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SOME RECENT DEVELOPMENTS IN EVALUATION AND UTILISATION OF UNCONVENTIONAL FEED RESOURCES

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Abstract: With increasing demand for livestock products, future hopes of feeding the millions and safeguarding their food security will depend on the better utilisation of unconventional feed resources that do not compete with human food. This calls for not only better utilisation of already known unconventional resources, but also for identification and introduction of new and lesser known plants capable of growing in poor soils, which can play a vital role in control of soil erosion, bring economic benefits to farmers, create jobs and bridge the wide gap between supply and demand for animal feeds. An important class of unconventional feeds is by-product feedstuffs which are obtained during harvesting or processing of a commodity in which human food or fibre is derived, and the amount of by-product feedstuffs generally increase as human population increase and economies grow. The role of buffaloes and cattle must increasingly be a scavenging one to make use of by-products, residues and other unconventional feeds. In Asia, ruminants in general and buffaloes in particular are fed low quality roughage in variable proportions depending on the type of animal and season. These feeds are poor in protein, energy, minerals and vitamins. Addition of foliage from tree spp. *Leucaena*, *Glyricidia*, *Calliandra*, *Acacia* etc. in buffaloes diets can improve the utilization of low quality roughage mainly through the supply of protein to rumen microbes, but presence of tannins in these tree foliage prevent not only their optimal utilisation but also of roughage and by-products. Tannins are generally present in high amounts in tree foliage and agroindustrial by-products. The availability and usage of various unconventional feed resources, including new and lesser known ones, the presence in them of deleterious factors and approaches to remove/inactivate these factors have been dealt with in several reviews and will therefore not be presented here. The purpose of this paper is to highlight the potential of a novel approach using an *in vitro* rumen fermentation technique for evaluation of nutritional quality of conventional and unconventional feed resources, and to describe general approaches for improving the nutritional quality of tannin-rich unconventional feed resources such as agro-industrial and forestry by-products and tree and shrub foliage. The reason for choosing tannin-rich unconventional feed resources is that tannins are the most widely occurring anti-nutritional factors in plants.

Keywords: Unconvention feeds, resources, evaluation, utilisation, tannins.

Introduction

In Asia, livestock especially buffaloes play an integral role in both the traditional small farming and intensive production systems. A major constraint to buffalo or cattle production in developing countries is the scarcity and fluctuating quantity and quality of the year-round feed supply. These countries experience serious shortages in animal feeds of the conventional type. The grain are required almost exclusively for human consumption. By the year 2020, the world population is expected to reach 8 billion and most of the population growth will occur in developing countries. With increasing demand for livestock products as a result of rapid growth in the world economies and shrinking land area, future hopes of feeding the millions and safeguarding their food security will depend on the better utilisation of unconventional feed resources that do not compete with human food. In addition, a total of approximately 1.2 billion hectares of land in the world are degraded barren or marginal and its proportion is increasing every year. This calls for not only better utilisation of already known unconventional resources, but also for identification and introduction of new and lesser known plants capable of growing in poor soils. This in turn can play a vital role in control of soil erosion, bring economic benefits to farmers, create more jobs and bridge the wide gap between supply and demand for animal feeds. Furthermore, diversification in traditional agriculture and conservation of biodiversity through the sustainable utilisation of harvests can be expected. An important class of unconventional feeds is by-product feedstuffs that are obtained during harvesting or processing of a commodity from which human food or fibre is derived. The amount of by-product feedstuffs generally increases as

the human population increases and economies grow. The role of buffaloes and cattle must increasingly be a scavenging one to make use of by-products, residues and other unconventional feeds. Buffaloes have an advantage over cattle in that buffaloes can better utilise poor quality roughage. In Asia, ruminants in general and buffaloes in particular are fed low quality roughage in variable proportions depending on the type of animal and season. These feeds are poor in protein, energy, minerals and vitamins. The addition of foliage from tree spp. such as *Leucaena*, *Glyricidia*, *Calliandra*, *Acacia* etc. in buffaloes diets can improve the utilisation of low quality roughage mainly through the supply of protein to rumen microbes. But the presence of tannins in these tree foliage prevents not only their optimal utilisation but also roughage and by-products. Tannins are generally present in high amounts in tree foliage and agroindustrial by-products (Makkar and Becker, 1996a; 1998).

The availability and usage of various unconventional feed resources, including new and lesser known ones, the presence of deleterious factors, and approaches to remove/inactivate these factors have been dealt with in several reviews (Liener, 1994; D'Mello, 1995a,b; Fadel, 1999; Makkar and Becker, 1999a). This information will therefore not be presented here. The purpose of this paper is to highlight (1) the potential of a novel approach using an *in vitro* rumen fermentation technique for evaluation of the nutritional quality of conventional and unconventional feed resources, and (2) to describe general approaches for improving the nutritional quality of tannin-rich unconventional feed resources, such as agro-industrial and forestry by-products, and tree and shrub foliage. The reason for choosing tannin-rich unconventional feed resources is that tannins are the most widely occurring antinutritional factors found in plants.

Evaluation of Feed Resources

Recent advances in ration balancing include manipulation of feed to increase the quantity and quality of protein and energy delivered to the small intestine. Selection of fibrous feeds based on high efficiency of microbial protein synthesis in the rumen along with high dry matter digestibility, and development of feeding strategies based on the high efficiency as well as high microbial protein synthesis in the rumen will lead to higher supply of protein post-ruminally. This concept of feed evaluation has an extra element of assessing the efficiency of microbial protein synthesis besides the dry matter digestibility. The limited supply of protein post-ruminally under most feeding systems in developing countries is an important limiting factor for increasing animal productivity.

There are a number of methods used to determine net microbial protein synthesis in the rumen, based on the use of microbial markers. They require the use of post-ruminally cannulated animals to determine flow of digesta. The cannulation approach is tedious and has several limitations (Chen *et al.*, 1990) to limit its applicability under most research conditions in developing countries. A simpler technique for determination of microbial protein supply to the intestine is based on the determination of total urinary purine derivatives (IAEA, 1997). This approach is being thoroughly investigated under a joint FAO/IAEA Co-ordinated Research Project (IAEA, 1998). Although the method is based on the collection of urine for determination of purine derivatives (allantoin, uric acid, xanthine and hypoxanthine), the approach is being further simplified using spot urine samples. This technique does not require cannulated animals, but it involves feeding of diets under investigation to animals and therefore is not suitable for screening a large number of samples or for developing feed supplementation strategies using various feed constituents.

In vitro methods

In vitro methods for laboratory estimations of degraded feeds are important for ruminant nutritionists. An efficient laboratory method should be reproducible and should correlate well with actually measured *in vivo* parameters. *In vitro* methods have the advantage not only of being less expensive and less time-consuming, but they allow one to maintain experimental conditions

more precisely than do *in vivo* trials. Three major biological digestion techniques are currently available to determine the nutritive value of ruminant feeds: (1) digestion with rumen micro-organisms as in Tilley and Terry (1963) or gas method (Menke *et al.*, 1979), (2) *in situ* incubation of samples in nylon bags in the rumen (Mehrez and Orskov, 1977) and (3) cell-free fungal cellulase (De Boever *et al.*, 1986). These biological methods are more meaningful since micro-organisms and enzymes are more sensitive to factors influencing the rate and extent of digestion than are chemical methods (Van Soest, 1994).

A simple *in vitro* approach is described below which is convenient, fast, and allows the handling of a large number of samples at a time. It is based on quantification of substrate degraded or microbial protein produced using internal or external markers, and of gas or short chain fatty acid (SCFA) production in an *in vitro* rumen fermentation system based on syringes (Menke *et al.*, 1979). This method does not require sophisticated equipment or the use of a large number of animals (one or preferably two fistulated animals are required) and helps selection of feeds or feed constituents based not only on the dry matter digestibility but also on the efficiency of microbial protein synthesis.

In vitro gas production with concomitant microbial mass measurement

Need for determination of microbial mass

Lately, the surge of interest in the efficient utilisation of roughage diets has caused an increase in the use of gas methods, because of the possibility of estimating the extent and rate of gas production in one sample by time series measurements of the accumulating gas volume. *In vitro* gas tests are attractive for ruminant nutritionists since it is very easy to measure the volume of gas production with time, but the measurement of gas only implies the measurement of the nutritionally wasteful and environmentally hazardous products. In most studies, the rate and extent of gas production has been wrongly termed as rate and extent of substrate (feed) degradation. Current nutritional concepts aim at high microbial efficiency, which cannot be achieved by measurement of gas only. *In vitro* gas measurements reflect only SCFA production. The relationship between SCFA and microbial mass production is not constant and the explanation for this resides in the variation of biomass production per unit ATP generated. This can impose an inverse relationship between gas volume (or SCFA production) and microbial mass production particularly when both were related to a unit substrate truly degraded. This implies that selection of roughage by measuring only gas by *in vitro* gas methods might result in a selection against the maximum microbial mass yield. Blümmel *et al.* (1997) have demonstrated how a combination of *in vitro* gas production measurements with a concomitant quantification of the truly degraded substrate provides important information about partitioning of fermentation products. The *in vitro* microbial mass production can be calculated as: Microbial mass = Substrate truly degraded - (gas volume x stoichiometrical factor). For roughage, the stoichiometrical factor was 2.20.

Partitioning factor

The parameters in the above equation also allow the calculation of partitioning factor (PF). The PF is defined as the ratio of substrate truly degraded *in vitro* (mg) to gas volume (ml) produced by it. A feed with higher PF means that proportionally more of the degraded matter is incorporated into microbial mass, i.e., the efficiency of microbial protein synthesis is higher. Roughage with higher PF has been shown to have higher dry matter intake. Different *in vitro* PF values are also reflected by *in vivo* microbial protein synthesis as estimated by purine derivatives (higher the PF, higher was the excretion of urinary purine derivatives; Blümmel *et al.*, 2000) and in methane production by ruminants (higher the PF, lower was the methane output; Blümmel *et al.*, 1999a). These results show that the PF calculated *in vitro* conveys meaningful information in the whole animal situation for predicting dry matter intake, microbial mass production in the rumen, and methane emission by ruminants.

The procedures for determination of truly degraded substrate and calculation of the stoichiometrical factor; stoichiometrical relationship between SCFAs and gas volume; and relationship between SCFA production, ATP production and microbial mass yield can be obtained from Blümmel *et al.* (1997) and Getachew *et al.* (1998a). It may be noted that these procedures and relationships are valid for substrates consisting predominantly of structural carbohydrates, and the findings might not extend to substrates such as those high in soluble carbohydrate, protein or fat. Rymer and Givens (1999) have shown that, as observed by Blümmel *et al.* (1997), good quality feeds (grass silage, wheat, maize, molasses sugarbeet feed and fishmeal) which produce a large amount of gas and SCFA yield small amounts of microbial mass per unit feed truly degraded. Further, Blümmel *et al.* (1999b) confirmed very close association (as per Wolin, 1960) between SCFA and gas production *in vitro* for a wide range of feeds consisting of a large number of dairy compound feeds and their individual feed components varying largely in protein and fat contents. The close association between gas and SCFA production also holds good for tannin-rich browses in the presence or absence of PEG (Getachew, 1999).

The stoichiometric balance allows calculation of CH_4 and CO_2 expected from the rumen fermentation if the molar proportion and amount of SCFA are known. It seems therefore justified to suggest the selection of feeds or feed ingredients with high *in vitro* true degradability but low gas production per unit truly degraded substrate.

Role of incubation time in PF determination

Another study by Blümmel *et al.* (1998a), in addition to once again describing the importance of measuring microbial mass, has highlighted the importance of the fermentation time at which the microbial mass needs to be measured. In this study, substrate degradation and kinetics of *in vitro* partitioning of three hays, with similar *in vivo* digestibilities, into SCFA, microbial mass yield, and ammonia. Carbon dioxide and methane production was examined at 8, 12, 18 and 24 h of incubation in the gas method under both low and adequate nitrogen levels. Microbial synthesis was quantified gravimetrically (Blümmel *et al.*, 1997), by nitrogen balance (Getachew *et al.*, 2000a) and by purine analysis (Makkar and Becker, 1999b). SCFA and gas production were positively correlated ($P < 0.0001$) and cumulative at all times of incubation under both low and adequate nitrogen levels. On the other hand, microbial mass, microbial nitrogen and microbial purine yields declined after 12 h of incubation while ammonia production increased. Gas or SCFA production was always inversely ($P < 0.05$) related to microbial mass yield regardless of incubation time and medium (low or adequate nitrogen) when related to a unit of substrate degraded. At later incubation times, continuously more SCFA or gas and continuously less microbial mass were produced reflecting microbial lysis and probably increasing microbial energy spilling. All three hays differed ($P < 0.05$) consistently in how the degraded substrate was partitioned into SCFA and gas and into microbial mass in both low and adequate nitrogen medium. Purine analysis indicated substantial differences in microbial composition across treatments, which might be one explanation for these different microbial efficiencies (Blümmel *et al.*, 1998a).

The efficiency of microbial growth was higher for 16 h incubation than 24 h for tannin-rich feeds when these were incubated in the presence or absence of PEG, a tannin-inactivating agent. Additional nitrogen in the medium also affected efficiency of microbial protein synthesis from tannin-tannins feeds both at 16 h and 24 h (Getachew *et al.*, 2000b). Approaches need to be developed for measuring the PF at the incubation time at which the lysis of microbes is minimal. Some possible simple approaches worth investigating so as to identify this incubation time are: (i) the time at which half of the maximum gas is produced, and (ii) the inflection point at which the rate of gas production is maximum (the rate increases up to an incubation time and thereafter decreases as the incubation progresses), both these parameters can be mathematically calculated from the gas profiles. The effect of nitrogen level of the medium on the PF and the significance *in vivo* of these PF also need to be investigated.

Digestion kinetics of neutral detergent-soluble fraction

The gas measurement method has also been used to study digestion kinetics of the neutral detergent soluble fraction of forages, starch-rich feeds and other highly digestible carbohydrate components, which was obtained by subtracting the average gas production curve for the digestible neutral detergent fibre (NDF) from that of the unfractionated whole feed (Chen *et al.*, 1999). The subtraction procedure might give some useful information for low-NDF fibre feeds, e.g., corn grain (Chen *et al.*, 1999), but it is not suitable for forages rich in NDF (Blümmel *et al.*, 1998b). Blümmel *et al.* (1998b) examined the rate and extent of fermentation of whole roughage and extracted NDF, dry matter degradability of extracted NDF and the PF for whole roughage and the extracted NDF of 54 roughage. The 24-h degradabilities of extracted NDF were higher than NDF degradabilities in whole roughage, and the PF values were lower for extracted NDF than for whole roughage (2.5 vs 3.1; i.e. lower efficiency of microbial protein synthesis for extracted NDF). Both the higher degradability and lower PF contributed to higher gas volumes obtained from extracted NDF compared with whole roughage. Supplementation of amino acids and sugars, which are essentially the solubles, may increase the efficiency of microbial synthesis from cell walls when incubated together (a situation similar to that in unfractionated forages) and the removal of solubles may result in lower microbial efficiencies. A considerable effect of cell solubles on partitioning of nutrients from the NDF causes doubts on the significance *in vivo* of the kinetic parameters calculated using the subtraction procedure (Blümmel *et al.*, 1998b).

Evaluation of silages and by-products rich in acids by the gas methods

Caution is required in the evaluation of acid-containing silages and by-products using the gas methods. Some silages (Davies *et al.*, 1998) and by-products such as citrus pulp and distillery by-products can have a substantial amount of acids. Since the gas methods (Blümmel *et al.*, 1997; Getachew *et al.*, 1998a) are based on incubation of the feed in a bicarbonate-based buffer, the acid present in the feed will release carbon dioxide from the buffer, which might be mistaken as fermentative gases, leading to erroneous results. This acid-base reaction is spontaneous and the gas released due to neutralisation of acids can be measured within 5 to 10 min of the start of the incubation. These measurements should be taken into account (subtracted from the gas production volumes) when measured at different times of fermentation before these gas values are used for evaluation of such feeds.

Protein degradability using the gas method

A method, based on the gas method (Blümmel *et al.*, 1997) and that of Raab *et al.* (1983), which measures gas production and ammonia in the medium has also been developed for measuring rumen degradability of nitrogen from low quality feeds (Getachew *et al.*, 1998b). These will also be useful in developing sound supplementation strategies and to increase the efficiency of utilisation of unconventional feed resources.

The 24-h *in vitro* degradable nitrogen values observed from tannin-rich browse and herbaceous legumes were lower than those reported for low quality roughage (Getachew *et al.*, 1998a; 2000a). However due to their relatively high crude protein content, browses and herbaceous legumes could play a significant role in supplying rumen degradable nitrogen. In presence of a tannin-inactivating agent, PEG, the *in vitro* degradable nitrogen values were higher. The difference between these values observed in presence and absence of PEG indicates the amount of protein protected by tannins from degradation in the rumen (Getachew *et al.*, 2000b). Whether this amount of protein protected by tannins from microbial degradation is fully available to animals post-rationally, requires further research. Raab *et al.* (1983) reported a close relationship between *in vivo* and *in vitro* values when incubation was terminated after 17 h. When normal proteins feed was used about 80 % of the 24 h value was degraded in the first 8 h incubation whereas in protected protein feed only 60% of the value measured after 24 h incubation were degraded (Raab *et al.*, 1983). The appropriate incubation time for *in vitro* degradability studies in

the presence and absence of PEG for tannin-rich feeds may depend on the nature of protein and tannins, which should be identified. This approach as a means for quantification of feed protein protected by tannins from degradation in the rumen needs to be validated *in vivo*.

Measurement of feed proteins during fermentation using poly-acrylamide gel electrophoresis coupled with the use of image analyser could be another attractive approach for measuring the rumen degradability of nitrogen, and to study the influence of various natural plant products (e.g., tannins, saponins, alkaloids; Makkar *et al.*, 1998a,b).

Evaluation of tannin-containing by-products and forage

Need to determine microbial mass using internal or external markers

The approach mentioned above for roughage for calculating microbial mass production based on the determination of truly degraded substrate by the detergent system of fibre analysis in the gas method was found to be meaningless for tannin-rich feeds. The PF calculated for tannin-rich feeds as mg truly degraded substrate needed to produce one ml gas ranged from 3.1 to 16.1 (Getachew *et al.*, 2000a) which is well above the theoretical range of PF (2.75 to 4.41) (Blümmel *et al.*, 1997). The high PF could be due to: (a) solubilization of tannins from the feed, thus, making no contribution to gas or energy in the system but contributing to dry matter loss, (b) cell solubles contributing to dry matter loss but inhibition of gas production from cell solubles by tannins, or (c) a combination of (a) and (b). In addition, the appearance of tannin-protein complexes as artefacts in the true residue also makes the gravimetric approach (Blümmel *et al.*, 1997) of quantification of microbial mass redundant (Makkar *et al.*, 1997a). The presence of tannin-protein complexes in faecal samples (the origin of proteins could be microbes, feed or endogenous secretion from the gastro-intestinal tract) from animals fed tannin-rich forage and their non-removal by the detergent system of fibre analysis (Van Soest *et al.*, 1991) leading to misleading values of fibre also causes problem in *in vivo* evaluation of tannin-rich feeds (Degen *et al.*, 1995; Makkar *et al.*, 1995a). Therefore, caution is required in the interpretation of results obtained from *in vivo* or *in vitro* experiments on evaluation of tannin-containing feeds using the detergent system of fibre analysis.

For *in vitro* evaluation of tannin-rich feeds, the microbial mass should be quantified using diaminopimelic acid or purines as markers, or by ^{15}N incorporation into the microbes (Makkar *et al.*, 1998a), and the PF for tannin-rich feeds can be described as microbial mass determined by these markers per ml of gas produced (or per mmol SCFA produced). The system developed for evaluation of tannin-containing feeds depends on incubation of the feed in presence and absence of polyethylene glycol (PEG MW 4000 or 6000 preferably of 6000; Makkar *et al.*, 1995b) and measurement of gas (or SCFA) and microbial mass using the above mentioned markers. PEG has a high affinity to bind to tannins. Addition of PEG results in the formation of PEG-tannin complexes, which inactivates tannins. The changes in gas (or SCFA) and microbial mass as a result of PEG addition represents 'in totality' the tannin effects (biological) as a function of rumen fermentation parameters. This bioassay based on *in vitro* rumen fermentation system coupled with the use of a tannin-complexing agent, polyethylene glycol (PEG) could be complementary to other tannin assays (Hagerman *et al.*, 1997; Makkar, 1989, 2000) in evaluating nutritional quality of tanniniferous feeds.

Significance of bound tannins and efficiency of microbial protein synthesis

The above approach of incubating tannin-containing feeds in presence and absence of PEG also enables studies on the nutritional significance of both extractable and unextractable (bound) tannins. Addition of PEG in the incubation of tannin-rich NDF led to increase in the gas production, suggesting that tannins released as a result of NDF degradation by rumen microbes are biologically active and have the potential to influence rumen fermentation (Makkar *et al.*, 1997b). Similar results were obtained on incubation of tannin-rich browses made free of

extractable tannins by repeated use of 70 % aqueous acetone. Another application of this method is to study the effect of tannins on partitioning of nutrients to microbial protein and SCFAs or gases or to study the efficiency of rumen microbial protein synthesis. Using DAPA, purines and ^{15}N approaches for measuring microbial mass it has been shown that in the presence of PEG although the degradability of substrate and microbial mass production were higher, the efficiency of microbial protein synthesis was lower. Similar results have also been obtained by another approach based on the gas method in which the rate of ammonia uptake is taken as the efficiency of microbial protein synthesis (Makkar *et al.*, 1998a). Conversely, efficiency of microbial protein synthesis is expected to be higher in presence of tannins. The net microbial mass production would depend on the balance between decreased degradable dry matter and higher microbial mass production per unit of dry matter digested in presence of tannins.

The *in vitro* gas method is more efficient than the *in sacco* method in evaluating the effects of tannins or other anti-nutritive factors. In the *in sacco* method these factors after getting released from the nylon bag are diluted in the rumen and therefore do not affect rumen fermentation appreciably. In addition, the *in vitro* gas method can better monitor nutrient-antinutrient and antinutrient-antinutrient interactions (Makkar *et al.*, 1995c). Several gas measuring techniques and *in vitro* gas methods are in use by several groups. Advantages and disadvantages of these methods are discussed by Gatechew *et al.* (1998a). The *in vitro* gas method based on syringes (Menke *et al.*, 1979; Blümmel *et al.*, 1997) appears to be the most suitable for use in developing countries.

Enhancement of Feeding Value

Various studies aimed at detanninification of tannin-rich feeds have been conducted. Two types of approaches were developed, one for farmers and the other for small-scale industries. The capabilities of farmers and small-scale industries were kept in mind so that the approaches could be easily adopted by the end users.

Farmer-based approaches

The woods of oak and pine are generally used as fuel in rural areas of the Himalayan region in India and adjoining countries. A 10 % solution of ash (pH, 10.5 - 11) decreased tannin levels in mature oak leaves by up to 80 % (Makkar and Singh, 1992a). Magadi soda (sodium sesquicarbonate, sodium carbonate and sodium bicarbonate), another unrefined material containing alkalies has also been shown to reduce assayable tannins in sorghum by 40 - 50 %. Wood ash solutions have also been used traditionally for treatment of high-tannin containing sorghum and millet for human consumption (for references see Makkar and Singh, 1992a). The use of wood ash, a cheap source of alkali holds potential for detanninification of tannin-rich feedstuffs.

Other major findings were: (i) a substantial reduction in the tannin content (72 - 89 %) on storage of fresh leaves, containing 55 % moisture and 4 % urea, for five days, and (ii) a reduction in tannin content of 46 - 60 % on storage of chopped leaves for 10 day (Makkar and Singh, 1993). The 'chopping of leaves and then storage' can find practical application for the farmers and can be adopted without any problem as it requires only a slight change in normal management practices. Instead of feeding the leaves on the same day as they are lopped, they need only be chopped and stored for about five to ten days before feeding. The use of urea calls for resources and some degree of education - the lack of which has hindered the adoption of this approach. The higher extent of inactivation of tannins by chopping of leaves could be due to oxidation of tannins by phenol oxidases present in leaves, as chopping is expected to increase the availability of tannins to the enzyme. In addition, inactivation of tannins during storage is due to their polymerisation to higher 'inert' polymers (Makkar and Singh, 1991a, 1993). Another factor responsible for enhanced effects observed on urea addition could be the higher pH caused (Makkar and Becker, 1996a) by evolution of ammonia from urea. Similarly, inactivation of tannins observed when using wood ash is also mediated by high pH-mediated oxidation of tannins.

Approaches for small scale industries

Drying under different conditions (Makkar and Singh, 1991b) and steaming and autoclaving (Makkar and Singh, 1992b) were found to be not very effective for oak leaves. Extraction with organic solvents (acetone, methanol, ethanol) and treatment with oxidising agents (potassium dichromate, potassium permanganate and alkaline hydrogen peroxide) were very effective and removed/inactivated up to 90 % of the tannins in oak leaves (Makkar and Singh, 1992c) and up to 99 % in agro-industrial and forestry by-products (Makkar and Becker, 1996a). The use of oxidising agents holds promise for the large-scale detoxification of tannin-rich feedstuffs because of its low cost. These approaches are very simple, do not require complex equipment and are likely to be adopted by the feed industry in the future both in developing and developed countries. In addition, potassium permanganate is easily available in villages in developing countries (generally used for cleaning water in wells), is non-corrosive and hence farmers can use this chemical at home for detanninification of tannin-rich feedstuffs. The use of organic solvents for extraction of tannins has an advantage over oxidising agents as the tannins can be recovered for the tanning of leather or for other industrial applications. The oxidising agents convert tannins to quinone, which are not capable of forming tannin-protein complexes under normal physiological conditions. However, the use of organic solvents is expected to be more expensive, except if the value of tannins recovered is higher than the cost of organic solvents used in the treatment.

The use of white-rot fungi (*Sporotricum pulverulentum*, *Ceriporiopsis subvermispora* and *Cyathus steroreus*) known to degrade lignin decreased tannin content by about 60 % in 10 to 20 days of fermentation (Makkar *et al.*, 1994; Gamble *et al.*, 1996). This approach though presently in its infancy, may also find a place in industry in the future.

The above technologies for detanninification of tree leaves on a small scale industrial level do not seem to be economically viable because large quantities of leaves are seldom available in one place (unlike agroindustrial by-products) and the cost of collecting them is high. There is a lack of information on judicious lopping of tree leaves and strict control, especially in developing countries, on the extent of lopping. Even if the information were available, its application would seem to be difficult, particularly when interests of industries for detannifying or making protein supplements from trees or shrubs are at stake. However, the detannification technologies presently available may well set the stage for utilisation of agro-forestry by-products including tree pods.

Use of PEG by farmers and by the feed industry

Addition of a tannin-complexing agent, PEG to tannin-rich diets is another attractive option to enhance feeding value of such diets. This approach can be used both by farmers as well as by the industry. Farmers can apply PEG directly to animals through water, by mixing in a small amount of concentrate, by spraying on tannin-rich feedstuffs or better as a part of nutrient blocks (see below). Industry can incorporate PEG in a pelleted diet composed of ingredients including tannin-rich by-product(s). Amongst various tannin-complexing agents investigated, PEG of molecular weight 6,000 was the most effective in binding to tannins at near neutral pH values (Makkar *et al.*, 1995b). Incorporation of PEG has been shown to have beneficial effects in monogastrics and both beneficial and adverse effects in ruminants (Table 1). The incorporation of PEG had beneficial effects for feedstuffs such as *Quercus calliprinos*, *Pistacia lentiscus*, *Ceratonia siliqua* (Silanikove *et al.*, 1994, 1996, 1997), *Zizyphus nummularia* (Kumar and Vaithyanathan, 1990), *Hedysarum coronarium* (Stienezen *et al.*, 1996), *Acacia aneura* (Eady *et al.*, 1990; Pritchard *et al.*, 1992, Ben Salem *et al.*, 1999), *Lotus pendunculatus* (Barry *et al.*, 1986; McNabb *et al.*, 1996) and *Desmodium ovalifolium* and *Flamingia macrophylla* (Barahona *et al.*, 1997) which are rich in tannins (condensed tannin content: 5 - 10 %). Inactivation of tannins through PEG increased availability of nutrients and decreased microbial inhibition, which in turn increased degradability of nutrients leading to higher animal performance. On the other hand, for *Lotus corniculatus*, the condensed tannin content of which varied from 2 to 4 %, addition of PEG decreased wool growth, weight gain (Wang *et al.*, 1994a; 1996a) and milk yield (Wang *et al.*, 1996b). This was attributed

to substantially lower absorption of amino acids from the intestine resulting from increased digestion of proteins in the rumen (Waghorn *et al.*, 1987). Addition of PEG to a diet containing 1 % condensed tannins through *L. corniculatus* did not have any effect (Waghorn and Shelton, 1997), suggesting that 1 % condensed tannin from *L. corniculatus* may be insufficient for protection of feed protein from degradation in the rumen. Lower performance of ruminants in presence of PEG could also be due to lower efficiency of microbial protein synthesis in the rumen (Makkar *et al.*, 1998a; see above). Besides concentration of tannins, the nature of tannins is another factor that would also influence response of animals to PEG incorporation. A diet containing 1.8 % condensed tannins through *L. pedunculatus* caused significant reduction in the levels of rumen ammonia and SCFAs and reduced nitrogen digestibility, whereas the same level of condensed tannins (1.8 %) from *L. corniculatus* had lesser effects (Waghorn and Shelton, 1997). The effect of PEG also depends on the level of proteins in the diet. Proteins mimic the effect of PEG - the higher the level of proteins, the lesser was the effect of PEG (Makkar and Becker, 1996b). It is evident from the literature that addition of PEG is advantageous when tannin content of the feed is high and is deleterious when tannin content is low (Table 1). There is some evidence that tannins in tropical plants are much more active (expressed as protein precipitation capacity per unit tannins) than temperate plants (Makkar and Becker, 1998), and therefore for tropical plants the addition of PEG might be beneficial even at low levels of condensed tannins. The characterisation of tannin-containing feeds in terms of parameter(s) representing the biological activity of tannins, such as protein precipitation capacity, will give a better insight into the role of tannins and in the development of approaches for their inactivation compared to measurement of only condensed tannins.

PEG has been incorporated into the diets at a level from 3 to 120 g per day, with varying responses. Supplementing sheep and goats, fed *Ceratonia siliqua* leaves, with 25 g of PEG/day seems to be the optimal amount in terms of cost-benefit response under Israeli conditions (Silanikove *et al.*, 1994). Although this technique is quite effective, success of its adoption will depend on the cost:benefit ratio. The effect of the manner of application of PEG (MW 6000) on some fermentation parameters at 24 h of incubation of tannin-rich feeds in the *in vitro* rumen fermentation system (mentioned above) has also been studied. PEG was applied as a single dose (51 mg) or in split manner (7 times, each time 7.3 mg at 0 h and then after every 2h interval) in incubations containing *Calliandra* leaves (protein precipitation capacity: 0.45 mg BSA pptd./mg feed). The gas and SCFA production increased substantially on addition of PEG. Purine as a marker for microbial mass was similar for control and single application of PEG but with split application the microbial mass was higher. Efficiency of microbial protein production was also higher with split application of PEG (Getachew *et al.*, 1999). The implications of these results are that PEG when given to animals on tannin-rich diets, in the form of molasses-mineral block licks (a slow consumption of PEG), would lead to better animal performance than when administered through currently used approaches, based on a single dose in drinking water or in a small amount of concentrate feed. Ben Salem and Nefzaoui (1999) have shown higher intake of *Acacia* leaves, higher nitrogen retention and greater urinary excretion of allantoin (a marker for microbial protein supply to the intestine) in sheep fed nutrient blocks containing PEG. But it would be interesting to compare these parameters when PEG is fed as a part of nutrient blocks and given as a single dose mixed in water or in a small amount of concentrate. Under the auspices of the IAEA, projects are now being planned for improving the utilisation of tanniniferous forages by feeding PEG-molasses-multinutrient blocks. The licking of these blocks will release PEG slowly, which is expected to supply higher microbial protein post-ruinally as a result of better efficiency of microbial protein synthesis mediated probably via better synchronisation of ATP production and release of nutrients.

Addition of PEG to tannin-containing feeds increased *in vitro* gas and SCFA production, and *in vitro* degradation of nitrogen. Therefore, there appears to be a potential to improve the utilisation of tannin-containing feeds without altering the genetic pool of tannin-containing plants with the use of a tannin-binding agent such as PEG. Inclusion of energy sources with the aim of synchronising nitrogen degradability and availability of energy increased the efficiency of

Table 1. The effect of addition of PEG* as tannin-binding agent to tannin-containing feeds on *in vivo* parameters in ruminants

Tannin-containing feed/tannin content	A. Negative effects of addition of PEG to tannin-containing feeds	References
<i>Lotus corniculatus</i> (CT 2.2 %)	- reduced the flux of essential and non essential amino acids through abomasum, reduced net apparent absorption of threonine, valine, <i>iso</i> -valine, leucine, tyrosine, phenylalanine, histidine and lysine	Waghorn <i>et al.</i> , 1987
<i>Herdysarum coronarium</i> (CT 4.7%)	- tended to decrease LWG, decreased rumen NH_3 -N	Terrill <i>et al.</i> , 1992
<i>Lotus corniculatus</i> (CT 3.5%)	- reduced wool growth and LWG	Wang <i>et al.</i> , 1994a
<i>Lotus pedunculatus</i>	- resulted in lower feed intake, tended to decrease LWG	Waghorn and Shelton, 1995
<i>Herdysarum coronarium</i> (CT 7.2 %)	- reduced LWG	Stienezen <i>et al.</i> , 1996
<i>Lotus corniculatus</i> (CT 3.4 %)	- reduced wool growth, LWG, and efficiency of feed utilisation; increased protozoa numbers	Wang <i>et al.</i> , 1996a
<i>Lotus corniculatus</i> (CT 4.5 %)	- low milk yield	Wang <i>et al.</i> , 1996b
B. Positive effects of addition of PEG to tannin-containing feeds		
<i>Lotus pedunculatus</i> (CT 4.6 - 10.6 %)	- increased N digestibility, increased intake of DOMI, total N, and ME	Barry and Duncan, 1984
<i>Lotus pedunculatus</i> (CT 7.6 - 9.0 %)	- increased LWG and wool growth	Barry, 1985
<i>Lotus pedunculatus</i> (CT 9.5 %)	- increased apparent OM and N digestibility	Barry <i>et al.</i> , 1986
<i>Acacia aneura</i>	- improved wool growth and LWG	Pritchard <i>et al.</i> , 1988
<i>Acacia aneura</i>	- higher LWG	Eady <i>et al.</i> , 1990
<i>Acacia saligna</i> (CT 2.8 %)	- increased DMI and LWG	Degen <i>et al.</i> , 1998
Concentrate + 15 % TA (Fluka)	- increased DMI and LWG	Degen <i>et al.</i> , 1998
Concentrate + 10 % Quebracho powder (5 % QT)	- increased DMI and LWG	Degen <i>et al.</i> , 1998
<i>Acacia cyanophylla</i> (CT 3.8 %)	- increased OMD, N digestibility, N retention and excretion of urinary purine derivatives	Ben Salem <i>et al.</i> , 1999
<i>Zizypus nummularia</i> (tannins 5.3 %)	- increased LWG, DMI, DMD, CP intake and CP digestibility	Kumar and Vaithiyathan, 1990
<i>Acacia aneura</i> (CT 8 %)	- increased intake, wool growth, digestibility of N and sulphur, reduced LWG	Pritchard <i>et al.</i> , 1992
<i>Ceratonia siliqua</i> (CT 5 %)	- increased OMI, OMD and live weight gain	Silanikove <i>et al.</i> , 1994
<i>Lotus pedunculatus</i> (CT 5.5 %)	- increased intake, rumen microbial turnover and N digestibility	Waghorn <i>et al.</i> , 1994a
<i>Lotus pedunculatus</i> (CT 5.5 %)	- increased DMI, DMD and total VFA	Waghorn <i>et al.</i> , 1994b
<i>Lotus corniculatus ad libitum</i> (CT 3.5 %)	- increased DMD, apparent digestion of N	Wang <i>et al.</i> , 1994b
<i>Lotus pedunculatus</i> (CT 4.5-5.5 %)	- increased dry matter and amino acid digestion	McNabb <i>et al.</i> , 1996
<i>Quercus calliprinos</i> (CT 5%), <i>Pistacia lentiscus</i> (CT 9.54), and <i>Ceratonia siliqua</i>	- increased LWG, OMD, DMI; NDF digestibility; rumen NH_3 -N	Silanikove <i>et al.</i> , 1996
<i>Desmodium ovalifolium</i> and <i>Flamingia macrophylla</i>	- increased feed intake	Barahona <i>et al.</i> , 1997
Pasture species (CT 0.12-0.47 %)	- tended to increase live weight gain and wool growth	Montossi <i>et al.</i> , 1997
<i>Quercus calliprinos ad libitum</i> (CT 9.5 %)	- increased VFI, and OM, CP, NDF digestibility	Silanikove <i>et al.</i> , 1997
<i>Lotus corniculatus</i> (CT 2.6 %)	- increased wool growth, N digestion	Waghorn and Shelton, 1997

CT, condensed tannin; CP, crude protein; DMD, dry matter digestibility; LWG, live weight gain; ME, metabolisable energy; N, nitrogen; NDF, neutral detergent fibre; OM, organic matter; OMI, organic matter intake; OMD, organic matter digestibility; * PEG molecular weight of 3 000 - 4 000; VFA, volatile fatty acid; VFI, voluntary feed intake; TA, tannic acid; QT, quebracho tannins.

microbial protein synthesis in the presence of PEG (Getachew *et al.*, 2000a). A rapid degradation of nitrogen not matched to the availability of energy could lead to high absorption of NH_3N from the rumen *in vivo*. In *in vivo*, the NH_3N not captured in the rumen is absorbed and converted into urea, and the synthesis of urea in the liver requires expenditure of energy; each mole of urea requiring four moles of ATP. The loss of nitrogen as urea in urine is energetically costly, is a loss of a valuable nutrient and causes environmental pollution.

Conclusions and Future Research

Research and development efforts are required to establish a feed library for nutritive values in addition to the routine composition analysis of unconventional feedstuffs. For tannin-containing feedstuffs besides measuring tannin levels by chemical methods, there is a need to incorporate approach(s) measuring the biological activities of tannins.

The *in vitro* rumen fermentation method, which concomitantly measures gas production and microbial mass production, has the potential to screen large number of feed resources. For example, it will have application in breeding programmes for development of varieties and cultivars of good nutritional value and in the development of supplementation strategies using locally available conventional and unconventional feed constituents to achieving maximum microbial efficiency in the rumen. It will also be useful in screening and in the study of the role of rumen modulators for increasing efficiency of microbial protein synthesis and for decreasing emission of environmental polluting gas, methane from ruminants. This method also provides better insight into nutrient-antinutrient and antinutrient-antinutrient interactions. The screening of plant-derived rumen modulators is gaining momentum due to their lower toxicity to animal and humans, and environmental friendliness, and as a result better consumer perception towards their use.

Further studies are required on: (i) the development of simple approaches for identification of the incubation time in the *in vitro* gas system, where PF (measure of the proportion of substrate fermented which leads to microbial mass production) is maximum, (ii) the effect of nitrogen in the incubation medium on the PF and (iii) the *in vivo* significance of the PF so obtained. The results of the limited experiments conducted so far have shown that simple models employing gas kinetic parameters and the PF are capable of predicting dry matter intake of roughage and emission of methane by ruminants fed a diet. Experiments also need to be directed towards validating the results from the digestion kinetic parameters including the PF, which screen feeds for maximum efficiency of microbial protein synthesis, with *in vivo* results by taking urinary purine derivatives (the most simple method available at present) as the measure of microbial protein supply to the intestine. This exercise should be conducted over a wide range of feed constituents and diets, which will enable the above mentioned simple technique of measuring gas and microbial mass to be a routine and powerful tool for feed evaluation without the need for time-consuming, laborious and high-input demanding feeding studies. Lately, much emphasis has been given to the development of statistical or mathematical models that fit best to the gas production profiles and describe the gas evolution with high accuracy. Experiments must be designed to understand the biological significance of various statistical and functional parameters being calculated using these models, and also to incorporate a measure of microbial mass into these mathematical descriptions.

Enhancement of the feeding value of tannin-rich feeds can be achieved by anaerobic storage in the presence or absence of urea; by the use of oxidising agents, white rot fungi or PEG in the slow release form; or by the addition of PEG and energy sources to forages rich in tannins or to tannin-rich byproducts low in energy with the aim of synchronising nitrogen degradability and availability of energy to increase the efficiency of microbial protein synthesis. PEG as a part of 'nutrient blocks' besides better incorporating the nitrogen of feed into microbial mass will also allow the livestock to self-regulate the intake of PEG, thereby decreasing cost of the treatment.

The aim of future studies should be to explore the potential of these approaches for a wide range of tannin-containing feeds, and then to develop simple and economically viable detanninification approaches for use by farmers for feed resources such as foliage from trees and shrubs and for byproducts available to the farmers, and also for use by small scale industry for agroindustrial and forestry byproducts generally available in a large quantity at one place. These approaches will help to alleviate the problems posed by the disposal of various agroindustrial byproducts and the shortages of conventional feeds.

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RESPONSE TO MULTI-NUTRIENT SUPPLEMENTATION IN NILI RAVI BUFFALO AND SAHIWAL CATTLE UNDER SEMI-INTENSIVE MANAGEMENT IN THE DRY ZONE OF SRI LANKA

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Abstract: A study was conducted to compare the response of Nili Ravi (N) buffaloes and Sahiwal (S) cattle managed under a semi-intensive management system, with daytime grazing in the dry zone of Sri Lanka to supplementation of multi-nutrients. Twelve lactating cows each of N and S, and ten weaned calves each of N and S were used. N cows were divided into two groups ($n=6/\text{gp}$) balanced by milk yield (5.59 ± 0.5 l/d), body weight (612.3 ± 1.2 kg) and lactation length (78.65 ± 2.5 days). S cows also were divided into two groups ($n=6/\text{gp}$) balanced by lactation milk yield (7.15 ± 0.6 l/d), live weight (357.1 ± 2.0 kg) and lactation length (51.8 ± 2.0 days). N and S calves were also divided into two groups each ($n=5/\text{gp/species}$) balanced by body weight (67.3 ± 0.5 kg for N and 51.8 ± 0.7 kg for S) and age (103.4 ± 2.0 days for N and 86.1 ± 2.2 days for S). One group each of N and S cows were supplementarily fed with urea-molasses-mineral block (UMMB) containing urea, molasses, coconut poonac, rice bran, mineral mixture and cement at 10%, 40%, 20%, 12%, and 8% (w/w), respectively. The other two groups of cows served as the controls. One group each of N and S calves were supplemented with urea-molasses-mineral mixture (UMMM) containing urea, molasses, coconut poonac, rice bran and mineral mixture at 10%, 40%, 25%, 17%, and 8% by weight, while the other two groups of calves served as controls. Other management practices including grazing during daytime, feeding of concentrate mixture I at 2.5 kg/cow/day, and concentrate mixture II at 0.5 kg/calf/day. Measurements were obtained on individual daily intake of UMBB, UMMM, milk yield and fortnightly body weight. Blood samples were obtained from each animal every three weeks to determine blood urea nitrogen (BUN) and beta hydroxybutyrate (BHB). Representative samples of UMBB, UMMM, concentrate mixtures I and II were obtained periodically for proximate analysis. Daily ambient temperature (AT), relative humidity (RH) and rainfall (RF) were recorded. Data were subjected to analysis of variance. Mean daily temperature-humidity index varied between 73 ± 4 and 82 ± 1 diurnally. Both UMBB and UMMM were superior in nutrient content to concentrates I and II. UMBB and UMMM intake by treatment cows and calves increased with time. The daily intake of UMBB by N cows (0.292 ± 0.05 kg) and UMMM by N calves (0.096 ± 0.01 kg) were lower ($p < 0.05$) than that of S cows (0.381 ± 0.06 kg) and S calves (0.165 ± 0.02 kg). This is possibly due to greater recycling of plasma urea and susceptibility to heat stress in N compared to S and resulted in a significantly ($p < 0.05$) lower intake of energy and nitrogen through UMBB and UMMM by N cows and calves. Circulating BHB in N and S cows increased non-significantly ($p > 0.05$) upon supplementation, while that of N and S calves remained relatively stable. BUN increased ($p < 0.05$) upon UMBB and UMMM supplementation in both species. Supplemented groups of N and S experienced greater ($p < 0.05$) body weight gain and milk yield than respective controls. After the second week of the experiment, S cows experienced a greater rate of decline in milk yield compared to N cows reflecting a greater persistency in lactation in N cows. The results suggest that, while multi-nutrient supplementation is beneficial for both N and S, supplementary intakes of N were lower. Despite the lower intake and the greater maintenance requirement of N, the lactation and body weight responses were on par with those of S indicating the superior ability of N cows to utilize supplemented multi-nutrients (UMBB) even under thermally stressful semi-intensive management conditions in the dry zone of Sri Lanka.

Keywords: Multi-nutrient supplementation, intake, body weight, milk yield, buffalo, cattle.

Introduction

The improvement of the performance of buffalo and cattle, the two major dairy animals in Sri Lanka is an urgent need to meet the ever increasing demand for dairy products. In this context, many programmes including genetic upgrading of indigenous stock, importation of exotic breeds and improvement of plane of nutrition through supplementary feeding, have been launched in the past few decades. Attempts made to improve the plane of nutrition of buffalo and cattle through techniques, such as urea ammonia treatment or supplementation of straw have met with limited success, primarily due to low acceptance of the technology by farmers, because of the complexity and impracticability

of the techniques used. Still supplementary feeding remains as one of the promising alternative ways of improving the nutritional status of buffalo and cattle under Sri Lankan conditions. One of the latest introductions to the field of supplementary feeding in Sri Lanka is the urea molasses mineral block (UMMB) or multi-nutrient block. This block which provides nitrogen, energy and minerals, is easy to prepare using simple techniques familiar to the farmers. It has a long shelf life, hence can be prepared in advance for use over a period of time. It can be transported conveniently, and also the intake by animals can be controlled without much difficulty. All these advantageous qualities have contributed to its increasing popularity among livestock farmers as a supplementary feed. Although the limited number of studies conducted in Sri Lanka (Perera and Perera, 1996) investigated the feasibility and advantages of multi-nutrient supplementation, information is lacking on the comparative responses of cattle and buffalo to provision of the same multi-nutrient supplement, under semi-intensive management with daytime grazing in Sri Lanka. Hence this study was undertaken with the objective of comparing the responses exhibited by buffalo and cattle managed under semi-intensive conditions that allowed daytime grazing. The responses studied were feed intake, blood metabolites which are nutritional status indicators, body weight and milk yield, to the supplementary feeding of multi-nutrient blocks or mixtures.

Materials and Methods

This study was conducted at the National Livestock Development Board (NLDB) farm located at Nikaweratiya in the Kurunegala District in the Dry Zone of Sri Lanka. Twelve Nili Ravi (N) lactating cows and twelve Sahiwal (S) cows in early lactation, and ten weaned Nili Ravi calves, and ten Sahiwal calves were used. Nili Ravi cows were divided into two groups ($n=6/\text{group}$) balanced by milk yield ($5.59 \pm 0.7 \text{ l/d}$), body weight ($612.3 \pm 1.2 \text{ kg}$) and lactation length ($78.65 \pm 1.5 \text{ days}$). Sahiwal cows were also divided into two groups ($n=6/\text{group}$) balanced by lactation milk yield ($7.15 \pm 0.9 \text{ l/d}$), live weight ($357.1 \pm 2.0 \text{ kg}$) and lactation length ($51.8 \pm 1.5 \text{ days}$). Calves of the two breeds were also divided into two groups each ($n=5/\text{group/species}$) balanced by body weight ($67.3 \pm 0.5 \text{ kg}$ for N and $51.8 \pm 0.7 \text{ kg}$ for S) and age ($103.4 \pm 2.0 \text{ days}$ for N and $86.1 \pm 2.2 \text{ days}$ for S). One group of Nili Ravi cows and one group of Sahiwal cows were fed urea-molasses mineral block (UMMB) as a supplement, containing urea, molasses, coconut poonac, rice bran, mineral mixture and cement (w/w) at 10%, 40%, 20%, 12%, 8% and 10%, respectively. The remaining groups of cows (one group per species) served as the control. Similarly, one group each of the calves of N and S was supplemented with urea molasses mineral mixture (UMMM) containing urea, molasses, coconut poonac, rice bran and mineral mixture in the respective proportions of 10%, 40%, 25%, 17%, and 8% by weight. The other two groups of calves (one group each from N and S) served as the control for each species. With the exception of supplementary feeding, all the other management practices including free grazing during the day and provision of concentrate feed were maintained identical for all the groups of cows and calves. The concentrate mixture I, consisting of coconut poonac and rice bran in the proportion of 2:1, was fed at rate of 2.5 kg/cow/day at milking (0400 and 1600 hours) and concentrate mixture II (broiler finisher feed) were provided to calves at the rate of 0.5 kg/calf/day.

Data on hourly ambient temperature (AT), relative humidity (RH), and daily rainfall (RF) were recorded using a hygro-thermograph (Cole-palmer model SL 8368-50), and a rain gauge respectively, during the experimental period. The individual daily intake of UMMB and UMMM by treatment groups of cows and calves fortnightly, body weights and individual daily milk yield of cows were obtained. Beginning from day 0 (one day before commencement of supplementary feeding of UMMB and UMMM of the experiment, blood samples were drawn at three hours post feeding from all the animals, once every three weeks, to determine blood urea nitrogen (BUN) and beta hydroxy butyrate (BHB) concentrations. Representative samples of UMMB, UMMM, and the concentrate mixtures I and II were obtained periodically for proximate analysis.

The dry matter (DM), crude fiber (CF), nitrogen and crude energy contents of the feeds were determined using the standard analytical procedures (AOAC, 1980). Blood urea nitrogen and BHB contents in the collected blood samples were determined using the standardized nutritional metabolite

kits of the International Atomic Energy Agency (IAEA, 1993). The data concerning intake, body weight gain, milk yield and blood metabolites obtained from four groups of cows and four groups of calves were separately subjected to analysis of variance procedures (Snedecor and Cochran, 1979).

Results

Meteorological parameters

The ambient temperature (AT) and relative humidity fluctuated diurnally from $22.7 \pm 1.5^{\circ}\text{C}$ to $32.9 \pm 1.1^{\circ}\text{C}$ and 52% and 75% respectively, during 90 days of the experimental period which extended from early December to mid-March. Rainfall during the months of December, January and February were 72.1 mm, 42.2 mm and 7.0 mm, respectively. Based on the prevailed temperature and humidity conditions, the estimated mean temperature humidity index (THI) during the experimental period ($n=85$ days) fluctuated between 73 ± 5 and 83 ± 1 diurnally.

Proximate composition

Table 1 presents the proximate composition of UMMB, UMMM and that of the farm concentrate mixtures I and II offered to the cows and calves. The UMMB and UMMM offered to treatment cows and calves were superior in crude protein content to that of the concentrate mixtures I and II, which are normally offered in the farm as supplementary feed to all the cows and calves of the farm.

Table 1. Proximate composition of supplementary feeds (as % DM)

Item	UMMB	Concentrate I	UMMM	Concentrate II
Dry Matter %	82.33 ± 1.2	83.80 ± 3.0	79.60 ± 2.2	87.17 ± 2.3
Crude Protein	$25.10 \pm 1.3^*$	14.10 ± 0.8	$28.16 \pm 1.1^*$	18.66 ± 0.9
Crude Fiber	13.00 ± 0.6	15.10 ± 0.3	12.10 ± 0.3	13.70 ± 2.1
Gross Energy (kcal/g)	3.37 ± 0.4	3.18 ± 0.3	3.95 ± 0.3	3.40 ± 0.1

* differ at $p < 0.05$ to the value of the respective concentrate.

Intake

The intake of UMMB and UMMM by the treatment groups of cows and calves of Nili Ravi buffalo and Sahiwal cattle are presented in Table 2. The intake of UMMB and UMMM by the treatment groups of cows and calves increased with time ($p < 0.05$) from a mean value of 0.17 ± 0.02 kg/day/cow in the first month to 0.43 ± 0.04 kg/day/cow in the last month for N cows. The respective values for S cows were 0.22 ± 0.02 kg/day/cow and 0.50 ± 0.03 kg/day/cow. This resulted in an overall mean daily UMMB intake of 0.292 ± 0.05 kg per N buffalo cow, which was significantly lower ($p < 0.05$) than that of (0.381 ± 0.06 kg/day) S cows. The overall mean daily intake of UMMM by the N calves (0.096 ± 0.01 kg/calf/day) was also significantly ($p < 0.05$) lower than that of S calves (0.165 ± 0.02 kg per calf/day).

On 100 kg body weight basis, the differences in daily intake of UMMB and UMMM by treatment groups of N buffalo cows and calves compared to S cows and calves were more evident. This resulted in a significantly lower estimated gross energy and nitrogen intake by treatment groups of Nili Ravi buffalo cows and calves compared to that of treatment groups of Sahiwal cows and calves (Table 2).

Blood Parameters

Mean values of pre and post supplementation concentrations of circulating BHB and BUN of the four groups of cows and four groups of calves are given in Table 3.

Table 2. Mean daily intake of UMMB and UMMM by supplemented groups of cows and calves

Parameter	UMMB Cows		UMMM Calves	
	Nili Ravi	Sahiwal	Nili Ravi	Sahiwal
Mean Daily Intake				
(as fed)				
kg/d	0.292 ± 0.05	0.381 ± 0.06*	0.096 ± 0.01	0.165 ± 0.01*
g/100 kg BW/d	47.9 ± 2.3	106.5 ± 3.5*	142.5 ± 2.5	247.1 ± 4.5*
As DMI				
g/100 kg BW/d	39.3 ± 2.1	87.3 ± 3.2*	113.4 ± 2.2	196.7 ± 3.7*
Gross Energy Intake				
Kcal/100 kg BW/d	132.1 ± 0.2	290.2 ± 1.5*	447.3 ± 7.2	776.9 ± 10.1*
Nitrogen Intake				
(g/100 kg BW/d)	1.65 ± 0.9	3.64 ± 0.09*	4.92 ± 0.1	8.84 ± 0.2*

* Differ at $p < 0.05$ to the respective value in the same row of the other group

Beta hydroxybutyrate

In the four groups of lactating cows, the pre-supplementation BHB values were not significantly different (0.37 ± 0.03 mmol/l). Upon supplementation, the BHB of supplemented group of N buffalo cows and S cows declined, while that of the control N and S cows remained unchanged. However, the decline in BHB values of UMMB supplemented groups was not significant due to the high degree of animal variation within treatment groups. Pre-supplementation BHB values of the two groups of S calves were not different from each other but were slightly greater than the pre-supplementation BHB values of two groups of N calves. The BHB concentrations of the four groups of calves did not change significantly during the experimental period despite the treatments.

Blood Urea Nitrogen

The pre-supplementation BUN values of buffalo cows (3.57 ± 0.11 mmol/l) and that of Sahiwal cows (2.98 ± 0.13 mmol/L) were not significantly different between treatments. The BUN values of all four groups of cows increased during the treatment period. However, this increase over time was not significant for the two control groups, while both buffalo cows and Sahiwal cows supplemented with UMMB exhibited a significant increase of BUN values over the same period (Table 3). Mean pre-supplementation BUN values of the four groups of calves were not different ($p > 0.05$). The BUN values of the two control groups of calves remained relatively stable throughout the experimental period, while the BUN values of UMMM supplemented buffalo calves and Sahiwal calves increased significantly ($p < 0.05$) following supplementation (Table 3).

Body weight

The body weight of the four groups of lactating cows changed over time (Table 4, $p < 0.05$). During the experimental period, the buffalo cows supplemented with UMMB increased in body weight from 612.5 ± 1.2 kg to 645.2 ± 2.5 kg, while that of the control group increased to 632.1 ± 2.3 kg. This amounted to approximately a 380 ± 25 g of mean daily weight gain by each cow in the supplemented group and a 238 ± 21 g mean daily gain in the control group. On initial body weight basis, the total gain during the experimental period by the two groups of buffalo cows were 53 ± 7 g/kg and 32 ± 4 g/kg, respectively. During the same period, both groups of Sahiwal cows also gained weight. The UMMB supplemented S group gained a total of 21 ± 2 kg as opposed to 8 ± 0.7 kg body weight gain by the control S cows. In terms of daily weight gain, these values amounted to a gain of 261 ± 23 g/day, 95.2 ± 9 g/day, and 59.9 g/kg and 22.4 g/kg, respectively. Total body weight gain by the UMMB supplemented buffalo cows and Sahiwal cows were significantly greater ($p < 0.05$) than that of the control buffalo cows and control Sahiwal cows. The buffalo cows experienced a higher ($p < 0.05$) gain

than Sahiwal cows, while the daily gain also had the above explained relationship. Changes in body weight of the four groups of calves during the experimental period indicated that, the total gain was highest in UMMM supplemented Nili Ravi calves (27 ± 3 kg) followed by UMMM supplemented Sahiwal calves (26 ± 3 kg), control Sahiwal calves (22 ± 3 kg) and control Nili Ravi calves (21 ± 3 kg). Daily weight gains also followed the same order and were not significantly different.

Table 3. Response of blood parameters

Parameter	Pre –supplementation		Post supplementation	
	Nili Ravi	Sahiwal	Nili Ravi	Sahiwal
BHB (mmol /L)				
Cows				
UMMB supplemented	0.39 ± 0.02	0.34 ± 0.02	0.21 ± 0.07	0.27 ± 0.05
Control	0.36 ± 0.11	0.33 ± 0.11	0.34 ± 0.08	0.34 ± 0.08
Calves				
UMMM supplemented	0.25 ± 0.04	0.34 ± 0.04	0.24 ± 0.10	0.34 ± 0.10
Control	0.27 ± 0.06	0.32 ± 0.06	0.29 ± 0.06	0.39 ± 0.06
BUN (mmol /L)				
Cows				
UMMB supplemented	3.57 ± 0.11	2.98 ± 0.13	$4.55 \pm 0.08^*$	$3.68 \pm 0.38^*$
Control	3.60 ± 0.08	2.99 ± 0.16	3.64 ± 0.09	3.13 ± 0.09
Calves				
UMMM supplemented	3.31 ± 0.09	2.81 ± 0.13	$4.41 \pm 0.07^*$	$3.95 \pm 0.09^*$
Control	3.29 ± 0.12	2.78 ± 0.12	3.23 ± 0.08	2.85 ± 0.11

* Differ at $p < 0.05$ to pre-supplementation value of the respective group.

Table 4. Response of body weight of cows and calves

Parameter	Pre –supplementation		Post –supplementation	
	Nili Ravi	Sahiwal	Nili Ravi	Sahiwal
Cows				
Body weight (kg)				
UMMB supplemented	612.0 ± 1.2	357.5 ± 0.3	645.2 ± 2.5	378.9 ± 0.8
Control	612.5 ± 0.7	357.1 ± 0.5	632.1 ± 2.3	365.2 ± 0.6
Total BW gain (kg)				
UMMB supplemented			$32.0 \pm 2.5^*$	21.1 ± 2.0
Control			20.2 ± 2.4	8.1 ± 0.7
Calves				
Body weight (kg)				
UMMM supplemented	67.3 ± 1.1	52.1 ± 0.4	93.8 ± 2.2	77.8 ± 0.7
Control	67.4 ± 0.2	51.7 ± 0.5	88.2 ± 2.0	73.5 ± 0.6
Total BW gain (kg)				
UMMM supplemented			27.3 ± 2.9	26.2 ± 2.1
Control			21.1 ± 2.9	22.3 ± 3.0

Differ at $p < 0.05$ to the respective value in the same row

Milk yield

The daily milk yields of all four groups of cows changed ($p < 0.05$) during the experimental period (Figure 1). In UMMB supplemented Nili Ravi buffalo cows, the daily milk yield increased from a pre-

supplementation value of 5.59 ± 0.7 l/d/cow to reach a peak daily yield of 6.5 ± 0.5 l/d/cow in the 8th week of the experiment, but declined thereafter to reach 5.9 ± 0.6 l/d/cow in the final week. The control group of Nili Ravi cows also maintained daily milk yield up to the 9th week of experiment to reach 5.9 l/d/cow and declined to yield 4.9 l/d/cow in the final week. The group of UMMB supplemented Sahiwal cows increased daily milk yield from an initial value of 7.1 ± 0.9 l/d/cow to 7.4 ± 0.7 l/d/cow in the second week of the experiment and declined gradually thereafter to yield 3.3 ± 0.5 l/d/cow in the final week. The control group of Sahiwal cows declined daily milk yield to 2.7 ± 0.5 l/cow/day in the final week (Figure 1).

Although the S cows had a higher daily milk yield at the beginning of the experiment, at the end of the experimental period, the daily milk yield reached a value lower than that of buffalo. Both groups of N buffalo cows showed greater persistency in lactation compared to S cows (Figure 1).

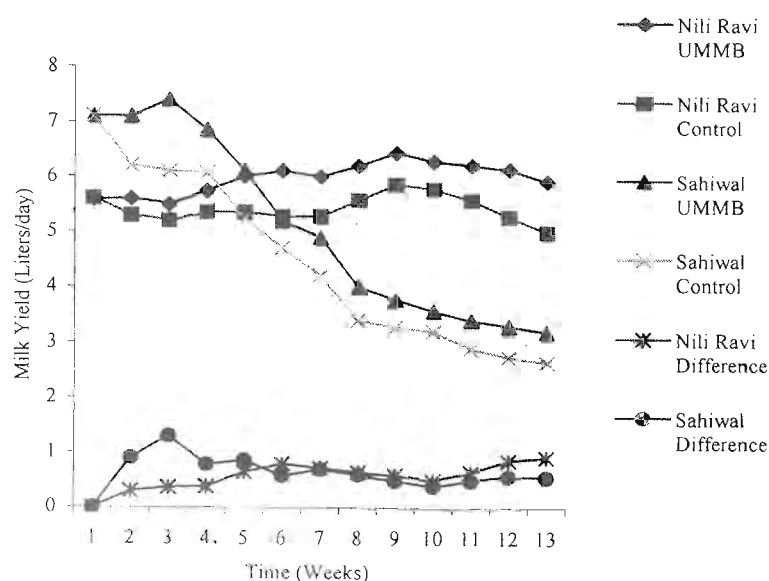


Fig. 1. Milk yield responses to UMMB supplementation in Nili Ravi buffaloes and Sahiwal cattle

Discussion

Thermal ambient conditions prevailed during the experimental period varied between a THI of 73 and 83. Environmental conditions with THI values between 72 and 78 exert mild stress, and 78 to 88 whole stress (Wiersma, 1990). Studies conducted in Sri Lanka under mild ambient conditions than the conditions that prevailed at Nikaweratiya during the experiment have indicated that environmental conditions become stressful for buffalo than for cattle between 1000 hours and 1600 hours. (Perera *et al.*, 1993). Thus it can be speculated that the N buffaloes, especially the lactating cows may have been subjected to greater heat stress compared to S cows during grazing periods. Heat stress impairs intake as a compensatory thermoregulatory mechanism. While this could be partly attributed to the lower ($p < 0.05$) intake of UMMB and UMMM by N buffalo cows and calves compared to S cows and calves (Table 2), the inherent nature of buffaloes to have lower dry matter intake per unit body weight than cattle (Pradhan, 1992) also would have been another cause. Due to lower intake of UMMB and UMMM by buffalo, the improvements brought in energy and protein intake through supplementary feeding of UMMB to N cows and UMMM to N calves were less than expected and lower than that of S cows and calves (Table 2). Comparable levels of UMMB daily intake by buffalo cows have been reported elsewhere (Kunju, 1986). Results on blood parameters indicate that circulating BHB in UMMB supplemented N cows and in UMMM supplemented N calves did not change significantly

in response to supplementation (Table 3). Circulating BHB reflects the balance between fat catabolism and ketone body utilization, and hence serves as an indicator of the energy status in ruminants (Lee *et al.*, 1978). BHB values decline in response to improvements in energy nutrition. The lack of a significant change in BHB in N cows and calves following supplementation suggest that supplementary feeding of UMMB to N cows and UMMM to N calves did not exert significant changes in energy status of these animals due to lower level of intake of UMMB and UMMM. The BHB values of the N buffalo and S cattle of this study are comparable to the values reported for cattle and buffalo in previous studies (Sahama *et al.*, 1994) and are within the normal range indicative of adequate energy status in cattle (IAEA, 1993).

The pre-supplementation BUN values were not different among different groups of calves and cows suggesting that the nutritional status of these animals before commencement of the experiment were comparable. The BUN values detected in this study were lower than those reported elsewhere for buffalo (Bertoni *et al.*, 1997), but were within the normal range reported for cattle (IAEA, 1993). Blood urea nitrogen of UMMB supplemented N and S cows, and UMMM supplemented N and S calves increased following supplementation. Such increases in BUN upon urea supplementation have been reported (Sahama *et al.*, 1994). Blood urea nitrogen indicates the balance between ruminally digestible protein and fermentable metabolizable energy in the rumen. Circulating BUN increases in response to feeding of poor quality dietary protein, inefficient protein utilization, carbohydrate deficiency and renal failure. The observed increase in BUN in both species of cows and calves in response to supplementary feeding of UMMB and UMMM was possibly an indication of inefficient protein utilization or the presence of poor quality dietary protein, as there was neither any indication of any of the animals having renal failure, nor the possibility of these animals consuming excess protein.

Body weight gain data indicates that all the animals were experiencing body weight gain during the experimental period and hence were in a positive balance. The UMMB supplemented cows were superior in weight gain to control. The improvement of body weight of both lactating group of cows supplemented with UMMB over their control counterparts, indicate the beneficial effects exerted by UMMB on lactating buffalo and Sahiwal cows. Total body weight gains of the two treatment groups of calves over their respective control groups were not significantly different, but on the basis of pre-supplementation body weight, UMMM supplemented groups had superior gains than the respective control groups indicating beneficial effects of UMMM supplementation. Milk yield response in N and S cows also confirms beneficial effects of UMMB supplementation. The S cows had a greater daily milk yield than N cows at the commencement of the experiment but declined gradually, and after the sixth week of the experiment, the daily milk yield of S cows became lower than that of N buffalo (Figure 1). At the end of the experimental period, S cows had much lower ($p < 0.05$) daily milk yield than N cows. This is despite the greater UMMB intake of S cows. The milk yield response of this experiment indicates that the persistency of lactation in buffalo cows was greater than that of Sahiwal cows.

Conclusion

The results of this experiment indicate that multi-nutrient supplementation in the form of UMMB and UMMM to lactating cows and weaned calves of Nili Ravi buffalo and Sahiwal cattle exerted beneficial effects on body weight gain and milk yield of both species. The intake of UMMB and UMMM respectively, by Nili Ravi buffalo cows and calves were lower than that of Sahiwal cows and calves, possibly due to heat stress and the inherent nature of buffalo to have lower dry matter intake per unit body weight than cattle. The BHB and BUN values in two species reflect lower energy and nitrogen intake by buffalo cows. The observed increases in body weight gain and milk yield of Nili Ravi buffalo compared to Sahiwal cattle, suggest that the efficiency of utilization of additional nutrients for milk production and growth in Nili Ravi buffalo were superior or in par with those of Sahiwal cattle, even under thermally stressful environment conditions.

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BUFFALO MILK PRODUCTION BY SMALL, MEDIUM AND LARGE FARMERS AND THEIR RESPONSE TO DIFFERENT INNOVATIONS IN PUNJAB (PAKISTAN)

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Abstract: The present study was planned to identify the different constraints that affect the buffalo milk production, farmers' response to innovations and new technology transfer and to devise recommendations and strategies to improve the situation. Three hundred and thirty two (322) respondents engaged in buffalo farming were interviewed and divided in two main classes, (i) landholding class (LHC) and (ii) animal holdings class (AHC). These classes were subdivided in landless, small, medium and large groups according to the land holdings and herd size. The collected data were used to identify the magnitude of different constraints affecting dairy production and farmers' response towards the new technologies and facilities introduced.

Finance, disease, expensive inputs, fodder and marketing were more important for medium farmers. Milk marketing was hitting 70% medium farmers. Fodder was major problem for landless farmers (41%), whilst minimum in large farmers (6%). Medium class was the most conscious about the improvement in farm productivity and income. This class with limited land and number of animals wants to maintain social status in culture. This is why it has shown the maximum concern in identifying the constraints. Analysis of data of "AHC" revealed that fodder production (57%), land (55%) and credit facilities (68%) were the major problems in small herds holding class. In case of medium herd class; land, fodder, veterinary cover, credit facilities; and in large herd class fodder and veterinary cover were of the main concerns. The structural composition of constraints revealed that land constraints were hitting the 55% small herd owners. The biggest constraints for large farmers were milk marketing and health cover. In spite of efforts of different NGOs and public sector, still natural insemination (N.I.) is considered to be the best and adapted by more than 95% farmers of every group. Another factor that plays an important role in practicing N.I is its 24 hours availability and poor extension services. Recommendations to overcome constraints are presented.

Keyword: Milk, production response, farm size

Introduction

Out of the 20.7 million heads of buffalo in Pakistan, Punjab supplies 73% of the total milk and 71% comes from buffaloes. The buffalo herds (43%) maintained by small farmers comprised animals of six or less than six animals (Anon., 1998). There are 0.5 million landless farmers keeping dairy animals and contributing a significant (70%) share of the total milk production.

The lack of proper health cover and disease control facilities from the government sector, the poor level of education, low genetic potentials of animals, uneconomical managerial practices, poor dairy replacement herd raising systems, use of low grade breeding bulls, poor artificial insemination (AI) services, malnutrition of animals, limited seasonal and poor quality feed resources and their unwise use, lack of new improved technology transfer and inefficient marketing systems are the main obstacles that animals owners have to face. Poor credit and marketing facilities, lack of necessary infrastructure, low labour productivity and managerial inefficiencies have a depressing effect on livestock income (Chaudhry *et al.*, 1997). Price fluctuations inherent in livestock sector and lack of livestock based industries are the additional factors depressing the income from this sector. Different NGOs and public sector institutions were involved in the improvement of the situation, but the output does not commensurate with the efforts made. Therefore, this study was planned to identify the different constraints that affect the

milk production, farmers' responses to innovations and technology transfer, and to devise recommendations and strategies to improve the situation.

Materials and Methods

Three hundred and twenty two farmers, living in 147 villages in central Punjab maintaining at least one dairy buffalo were interviewed using a pre-tested questionnaire. The households were randomly selected per village according to the procedure described by Poate and Daplyn (1993). The selected farmers were interviewed for 30 to 45 minutes based on questions relating to milk production, constraints faced by them and their views about new technologies introduced and suggestions. The data collected from farmers were used to categorise them according to land and animal holdings and further divided into subclasses. The landholding class LHC was subdivided to; (i) landless farmers (LL), (ii) farmers with less than 2 acres of land (small), (iii) from 2 to 12.5 acres of land (medium) and (iv) those with more than 12.5 acres (large). The farmers were also categorised according to the number of dairy animal as "Animal Holding Class" (AHC). The subclasses were as i) 2 or less than 2 animals (small), ii) from 2 to 6 animals (medium), and iii) more than 6 animals (large). The collected data were used to identify the magnitude of different constraints affecting dairy production and farmers' response towards the new technologies and facilities introduced.

Results and Discussion

Constraints faced by land holding class (LHC) and animal holding class (AHC)

The constraints expressed by respondents related to land, animals, labour, inputs, fodder, diseases control, milk-marketing, farm building and financial resources are given in Table 1. The importance and significance of problems was different in different groups. For landless and small farmers the land was a major constraint. They want to have land/more land to run their activities more efficiently. Finance, disease, expensive inputs, fodder and marketing were more important for medium farmers. In all groups finance, disease control and fodder constrains gained the substantial weightage. Medium class of farmers showed more concern about milk marketing.

Table 1. Classification of different constraints

	Land	Animals	Labour	Fodder	Input	Dist/Vet. services	Marketing	Tractor/Shed	Credit	Misc.
LHC				Percentage						
Landless	29	0	24	41	12	19	0	07	38	25
Small	24	0	14	18	06	08	0	07	16	19
Medium	42	100	43	35	55	45	70	43	43	38
Large	06	0	19	06	27	28	30	43	04	19
AHC				Percentage						
Small	55	67	33	57	37	34	20	36	68	56
Medium	31	33	57	27	39	36	40	36	25	31
Large	14	0	10	16	24	30	40	28	07	13

The structural composition of different constraints showed that problems of animal feeding ranked high among the landless and medium farmers, whilst it was minimum in large farmers. From Table 1, it is obvious that medium class is facing most of the problems and impact of different constraints is substantial on this class. This class is the backbone of our agriculture economy and the most conscious about the improvement in farm productivity and income. This class is having limited land and limited number of animals and with meagre resources, wants to

maintain social status in our culture. This is why it has shown the maximum concern in identifying the constraints (Pandy 1988; Apte, 1989).

Analysis of data of AHC revealed that fodder production, land and credit facilities were the major problems in small animal holding class. In case of medium herds class; land, fodder, veterinary assistance, credit facilities; and in large herd class fodder and veterinary assistance. were the main concerns. The structural composition of constraints revealed that land constraints were high in 55% small herd owners. The biggest constraints for large farmers were milk marketing and veterinary assistance.

The preview of different constraints suggests that fodder production was the biggest constraints in all groups, especially in landless, small and medium farmers. The inefficient marketing system was also pointed out by many groups of farmers, particularly large herd owners. If they could have better incentives, they would definitely improve the milk production and manage their dairy herd in a better way. The high cost inputs and poor returns have been criticized by many workers (Goswami and Rao, 1992; Deoghare and Bhattacharyya, 1994). There is need to launch credit facilities under a foolproof system. The "one window" credit facilities should be available to all classes of farmers, especially to small and medium farmers and it should be assured that credit is being dispensed to deserving candidate and utilized at the right place. It was noticed that if constraints pertaining to finance, inputs and marketing could be removed, even farmers with poor education and training can increase their dairy production and net income (Goswami and Rao, 1992).

The single dairy animal was another limiting factor. After completing the lactation, farmers have to feed the animal till the next calving. This practice increases the cost of milk production and makes it discouraging and a loss to the dairy enterprise. Dairy activity should be started at least with two animals to cope the dry period. The best way is to start with 4-6 animals, to have an income around the year (Bhende and Venkataram, 1994).

Response of farmers to new innovations and facilities

The farmers in the study area receive free artificial insemination services, vaccination, mineral supplements, and animal treatment facilities. They also received concentrate feeds (cotton seed cake) and seeds of improved fodder varieties.

The provision of AI service, vaccination, disease control and treatment of sick animals was available at doorstep but Table 2 shows that in spite of such a good package farmers still preferred the natural mating. This trend is highly associated with their education and state of unawareness. In spite of all efforts made by different NGOs and public sector, still natural service is considered to be the best and adapted by more than 95% farmers of every groups. Another factor that plays an important role in practising natural insemination (NI) is its 24 hours availability. Whilst, in the case of AI services, they have to take the animal to centre or contact the responsible person. It was observed that there was only one AI centre in the area. Most of the time farmers have to depute one person for this job or have to leave other activities. Sometimes they were intensively engaged in other agriculture activities that were not able to spare someone for this purpose. The silent heat in buffalo was another problem. It was also observed that insemination was not done at proper time. Either it was too early or too late. Considering all these factors, the vast majority of farmers preferred the natural service without considering the genetic potential of the bull. As sire is half of the herd, this practice is causing the propagation of genetically inferior offspring in area.

The use of vaccination and dewormers is also under question (Tables 3 and 4). The study showed that majority of the farmers were getting their animals vaccinated and dewormed. Only a small proportion (5-15%) of farmers were not getting facilities of vaccination or deworming (Tables 3 and 4). Such a high % of vaccination and deworming seems surprising when we see their

response towards AI. It could also be possible that they made this claim to show themselves as progressive farmers (Teufel, 1998).

Table 2. Vaccination by farmers (%) in different groups

	Land holding class			
	Landless	Small	Medium	Large
No vaccine	13	10	06	08
HS	01	00	02	00
HS and FMD	86	90	92	92
Animal holding class				
No vaccine		11	07	05
HS	-	01	02	00
HS and FMD	-	88	91	95

Table 3. Types of insemination (%) in different groups

	Land holding class			
	Landless	Small	Medium	Large
AI	01	05	05	08
N.I.	99	95	95	92
Animal holding class				
AI	-	05	04	04
N.I.	-	95	96	96

Table 4. Deworming (%) by farmers in different groups

	Land holding class			
	Landless	Small	Medium	Large
No Deworming	41	24	26	35
Local	06	07	07	02
Commercial	53	69	70	61
Local and commercial	0	0	0	02
Animal holding class				
No Deworming	-	35	24	35
Local	-	07	02	05
Commercial	-	58	74	60
Local and commercial	-	0	01	0

To provide free treatment Idara-e-Kisan (NGO) has appointed "Village Veterinary. Assistants" (VVA) in villages, but still a higher % of farmers was not satisfied with veterinary services. Either the staff is not quite competent for the services or not available at the required time. The malpractice and behaviour of responsible person could be another reason.

The Government sector and NGOs both are trying to help the farmers to improve their production and enhance family, income but the output do not commensurate with the amount of investment and efforts made (Jena, 1988). They still are not able to eliminate a single factor "Dodhi" (middleman) who is competing alone with 3 Govt. departments viz., extension, Agriculture Development Bank (ADBP) and veterinary. He is one of them and is the quickest means to get loan for farmers. He gives them loan without interest; in return he gets milk at cheaper rate. He supplies farmers provisions, participate in their social life events and helps in animals medication. He has got great influence on rural dairy industry. Most of the farmers have taken loans from "Dodhi" and are obliged to sell their milk to him at low prices. However they are willing to join IK but are committed to Dohi. If loans were made available against suitable security, without the involvement of much paper work and red-tapeism, it would be possible for them to purchase good

quality animals and inputs. This along with better extension services and giving farmers due "honour" would help to improve the situation. The financial assistance at right time with efficient marketing for their products is vital to run dairy system (Jena, 1988).

Conclusions

The following conclusion could be suggested from the data obtained from this study

- The landless and small farmers were substantially dependent on the revenue from the sale of milk and other animal products to meet the daily household expenditures.
- The large farmers with larger herds of animals had minimum motivation for improvement. They depend more on the crop sector. The large numbers of animal are mainly maintained as a matter of prestige and to fulfil home and labour requirements. No attention is given to the commercial exploitation of livestock herd.
- The feeding is quite poor. Concentrates are only fed during the first few months of lactation. Most of the feeding comprised roughage and grazing on river/canal/road/field sides.
- The lactation length was slightly longer in landless farmers than land owning groups, but average lactation yield was almost similar.
- The animals owned by the landless farmers showed longer calving interval than those of the other classes of farmers.
- The feeding cost showed the highest % share in the total cost of production of milk and it affected the lactation length as well as yield, leaving farmers with minimum profit and making it losing enterprise.
- Constraint analysis showed that feed cost, veterinary services, milk marketing and credit facilities were on top ranking.
- The small to medium land owners or herd owners were more concerned about the improvement of their animals and to uplift their family income.

The above-mentioned factors directly or indirectly affect the milk production in study area. To improve the situation and milk production, following recommendation one proposed to develop an effective approach:

Recommendations

- The data expressed that medium farmers have the higher percentage in our land distribution table and need attention, because they are playing a vital role in agriculture and livestock production activities. Before preparing any package or reforms (lend or livestock) their response should be given due weightage.
- The "one window" credit facility should be available to landless small and medium farmers for dairy enterprise, as is prevailing in India. The loan should be sanctioned for at least a unit of 5 buffaloes/cattle at minimum interest rate and smaller return instalments.
- To exclude the middleman "Dodhi" a better and efficient marketing system should be devised. Availability of easy credit facilities, excellent extension service and individual respect can give the favourable results. The village associations can play important role in this respect.
- The feeding system and fodder availability should be improved. The high quality seeds and multi-cut fodder varieties should be provided to farmers.
- Inexpensive balanced dairy rations should be prepared on a commercial scale and introduced in the rural areas.
- To reduce the calving interval through shorter service period, attention to balanced feeding after calving should be given. The balance feeding will not only reduce the service period but also increase the lactation yield and economic return.
- The poor genetic make up is another problem associated with poor output in the area. The N.I. without considering the genetic qualities of bull is the single biggest reason for the increase in

poor quality animals in the area. If, A.I is not feasible or the farmers are facing problems, then genetically high quality bulls should be introduced into the area at breeding charges.

- It was observed that most of the problems were related to poor literacy rate and use of conventional practices. The focus on the education of farmers, especially school going children should be concentrated. Because these children are future farmers, they play an important role in looking after the animals; and by training them at a younger age (about animal keeping) the many livestock production problems can be minimised.
- The Women farmers (also called, absent farmers) can play a major role in improving the animal production. Traditionally to look after the dairy animal is also the responsibility of women and they spend a major part of their daytime in taking care of animals, such as feeding, washing to milking. Provision of proper production-oriented training can easily solve the many problems and help in enhancing the milk production and family income.
- The silent heat in buffalo is a major problem. The use of teaser bull and mating in the morning and evening should be introduced in the area and farmers should be educated about the reproductive behaviour of buffalo.
- The extension services should be more practical, simple and well-planned; and based on farmers' participatory principles.
- Although some of the above mentioned steps are being taken in some areas but organizational and staff problems could be the reasons for poor response to these innovations.
- Farmers should be stimulated to run the dairy industry as commercial enterprise rather than an offshoot of agriculture.
- Farmers' day should be arranged to share farmers' views, experiences and feelings; and to introduce new technologies to them.
- The trained and educated farmers should be given preference over other candidates in granting loans. It will produce an incentive to more trained, educated and progressive farmers to be motivated and adopt new ideas.

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STRAW AND FODDER BASED SUPPLEMENTATION FOR BUFFALOES

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Abstract: The major determinants of ruminant production systems are the agro-ecology, cropping pattern and land availability. The most prevalent system in Sri Lanka is the dry zone traditional production system or the "Purana" village system. The predominant genotypes are indigenous zebu and indigenous buffaloes on communal grazing lands. The management inputs are very marginal except, the labour spent on moving with large herds, along the areas of communal grazing lands. The return from the operation is substantial and the primary income is from selling of animals and milk. The use of draught in paddy cultivation is not uniform due to the introduction of mechanical power in recent times. This system, however is threatened with increased pressure on land due to expansion of settlement schemes. Therefore, both the quantity and quality of forage seem to limit the full realization of the genetic potential of even the commonly available indigenous stock. Therefore, main objective of this study was to develop straw and fodder based supplementary feeding systems for buffaloes in Sri Lanka.

Keywords: Feed supplementation, roughage based, rations.

Introduction

The major determinants of ruminant production systems are the agro-ecology, cropping pattern and land availability. The most prevalent system in Sri Lanka is the dry zone traditional production system or the "Purana" village system. The predominant genotypes are indigenous zebu and indigenous buffaloes that are reared on communal grazing lands. The management inputs are very marginal except the cost of labour spent on moving with large herds, along the areas of communal grazing lands. The return from the operation is substantial and the primary income is from the sale of animals and milk. The use of draught in paddy cultivation is not uniform due to the introduction of mechanical power in recent times.

This system however is threatened with the increasing pressure on lands due to the expansion of human settlement schemes. Therefore, both the quantity and quality of forage seem to limit the full realization of the genetic potential of even the commonly available indigenous stock. Therefore, the main objective of this study was to develop straw and fodder based supplementary feeding systems for buffaloes in Sri Lanka.

Materials and Methods

Fodder collection and identification

Fodder, grasses, feeds and agro- industrial by-products consumed by buffaloes were collected from buffalo farms. These samples were identified using the morphological characteristics of the plants.

Chemical composition of fodder and feeds

Samples were brought to the laboratory and dried in an oven at 70⁰ C till a constant weight was obtained. Dried samples were ground to passed through a 1 mm sieve and used for chemical analysis such as dry matter (DM), ash, crude protein (CP) (AOAC, 1980), ether extract (EE) (AOAC, 1980), crude fiber (CF) (AOAC, 1980), neutral detergent fibre (NDF) (Van Soest and Wine, 1967), acid detergent fibre (ADF) (Van Soest, 1963), lignin (LIG) (Van Soest and Wine, 1968), *in vitro* dry matter digestibility (IVOMD) and *in vitro* organic matter digestibility (IVOMD) (Tilley and Terry, 1963).

Ration formulation

Rations were formulated for different groups of buffaloes (weight of buffaloes were 100, 150, 200, 250, 300 and 350 kg whereas, weight gain of buffaloes were 0, 0.25 and 0.50 kg/day) for energy and digestible crude protein using the available feeds collected from the farmers.

Results and Discussion

Table 1 presents the grasses, shrubs and fodder consumed by buffaloes. According to Table 1, twenty two types of grasses, fodder, shrubs and agro-industrial by-products have been identified and most of these plants were consumed by the majority of buffaloes.

Table 1. Grass and fodder varieties consumed by buffaloes

Code No.	Common name	Botanical name
1	Bana grass	<i>Pennisetum purpureum</i> * <i>Pennisetum americanum</i>
2	Banana leave	<i>Musa paradisiaca</i>
3	Bracharia brizantha	<i>Bracharia brizantha</i>
4	Bracharia mutica	<i>Bracharia mutica</i>
5	Cassava leaf	<i>Manihot esculenta</i>
6	Erythrina	<i>Erythrina indica</i>
7	Glyricidia	<i>Glyricidia sepium</i>
8	Green panic	<i>Panicum maximum</i>
9	Guatamala	<i>Tripsacum laxum</i>
10	Guinea-A	<i>Panicum maximum</i> , eco type "A"
11	Hamil	<i>Panicum maximum</i> , eco type "Hamil"
12	Ipil-Ipil	<i>Leucaena leucocephala</i>
13	Jak leaf	<i>Artocarpus heterophyllus</i>
14	Jak seeds	<i>Artocarpus heterophyllus</i>
15	Natural grass, (paddy fields)	
16	Natural grass, (road side)	
17	NB21	<i>Pennisetum purpureum</i>
18	PGN	<i>Pennisetum purpureum</i>
19	Straw- untreated	<i>Oryza sativa</i>
20	Straw- treated	<i>Oryza sativa</i>
21	Guinea VRI 435	<i>Panicum maximum</i>
22	Wild sunflower	<i>Thitonia diversifolia</i>

Table 2 presents the chemical composition of grasses and fodder consumed by buffaloes. Crude protein contents of these feeds ranged from 4.3% (untreated straw) to 28.8% (Ipil-ipil) and crude protein contents of almost all grasses were lower (4.3 to 14.5%), that of legumes (19 to 26%) and other fodder (13.8 to 28.3%). Digestibility values ranged from 43.6% (Jak leaf) to 70.1% (*Bracharia mutica*) whereas digestible crude protein content was lowest in untreated straw (5g/kg) and highest in wild sunflower (227 g/kg).

Digestible crude protein contents of grasses (61 to 104 g/kg) were lower when compared with legumes (139 to 215 g/kg). Energy content of Banana leaves (4.3 mcg/kg) was much higher when compared to all other feeds. Energy content of grasses ranged from 1.5 mcg/kg to 2.8 mcg/kg whereas the energy content of legumes were ranged from 1.8 to 3.6 mcg/kg. However, the energy value of Jak seeds was very much higher (4.0 mcg/kg) when compared to grasses and legumes.

Tables 3 - 8 presents the formulated rations for buffaloes weighing 150 kg and 250 kg. Rations formulated for buffaloes weighing 100, 200, 300 and 350 kg are not given in this paper due to lack of space. However, 411 rations have been formulated for different weight groups of buffaloes using these 22 feeds.

According to Table 3, 18 feeds were used in formulating 21 feed mixtures for buffaloes weighing 150 kg for maintenance. Out of the 18 feeds used in Table 3, banana leaves, treated straw and untreated straw were used in most of the rations for buffaloes. These rations were sufficient for maintenance of animals. In Table 4, 17 feeds were used in formulating 22 feed mixtures for buffaloes weighing 150 kg having a weight gain of 0.25 kg/ day. Feeds such as untreated straw, straw, *Brachiaria brizantha*, *Brachiaria mutica* and banana leaves are common in most of the mixtures and these feeds are freely available during the dry season in the areas where buffaloes are reared.

Table 5 presents the feed mixtures for buffaloes weighing 150 kg, gaining 0.5 kg/day. Twenty three feed mixtures were formulated using 15 feeds. Untreated straw, straw, Pusa Giant Napier (PGN), *Brachiaria brizantha*, Hamil, *Brachiaria mutica*, gliricidia and banana leaves were included in most of the mixtures.

According to these three Tables, it is evident that roughages and poor quality forages can be used as maintenance diets, whereas high quality forages and legumes have to be used for production purposes (Table 3, 4 and 5). A similar pattern has been observed with the buffaloes weighing 250 kg (Table 6, 7 and 8).

Table 9 presents the amount of feeds added to mixtures as a % on dry matter basis. According to these Tables, banana, untreated straw, straw, natural grass (roadside grass), *Brachiaria brizantha*, PGN, Hamil, gliricidia, *Brachiaria mutica* and Guinea "A" can be used in large quantities together with other fodder and shrubs to formulate buffalo rations. These rations can be used by farmers together with a mineral mixture to feed buffaloes for maintenance or body weight gain.

Conclusion

Formulated rations can be used by farmers for different groups of buffaloes together with a mineral supplement.

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Table 2. Chemical composition of grass and fodder varieties consumed by buffaloes.

Feed	Dry matter %	Ash %	Crude protein %	Digestibility %	Energy mcal/kg	Digestible crude protein g/kg
Bana grass	19.0	13.0	09.0	61.0	2.0	51
B. brizantha	20.0	08.5	10.6	-	2.2	71
B. mutica	19.5	10.0	12.3	70.1	2.4	35
Green panic	19.4	08.4	12.0	49.9	1.7	82
Guathamala	20.0	10.5	09.8	-	2.0	61
Guinea-A	20.5	08.7	14.1	59.4	2.1	100
Hamil	19.5	11.9	09.6	51.3	1.7	63
Natural grass, paddy	16.0	11.0	14.5	52.4	1.8	104
Natural grass, road/g	18.5	10.0	14.0	42.2	1.5	97
NB21	16.0	13.9	14.4	61.1	2.1	98
PGN	18.0	08.9	12.4	-	2.8	86
Straw, untreated	94.0	15.5	04.3	52.1	1.7	05
Straw, treated	94.0	15.6	06.5	58.8	1.9	23
VRI 435	24.0	08.3	13.2	-	1.9	93
Banana leaves	17.0	10.0	12.0	-	4.3	78
Cassava leaves	20.0	08.0	27.0	-	2.0	211
Erythrina	25.0	12.5	26.0	57.9	1.8	197
Glyricidia	27.0	06.0	19.0	68.9	3.5	139
Ipil-Ipil	31.0	03.4	28.8	54.2	3.6	215
Jak leaf	32.0	10.0	13.8	43.6	1.7	94
Jak seed	94.9	-	14.7	-	4.0	95
Wild sunflower	15.5	14.4	28.3	49.1	1.9	227

Table 3: Weight of buffalo - 150 kg - Maintenance.

Type of Feed	Serial No	Code No. *																		Total wt (kg)
		20	19	17	16	18	3	15	11	21	1	8	4	10	9	2	5	6	22	
F E E D	1		1.0						3.5								2.4			9.5
	2		2.1						4.6							3.9				4.5
	3										4.7									8.6
	4	1.6																		6.3
	5		1.4										5.0							6.4
	6	2.2																1.8		3.9
	7									2.0						4.8				6.8
	8												3.5			3.8				7.3
	9						4.6									3.3				7.9
	10		0.6								9.2									9.7
M I X T U R E S	11	1.8						4.2								3.0				6.0
	12					4.5												2.0		7.5
	13		2.2															1.3		4.2
	14	2.2																		3.4
	15														5.9	2.8				8.7
	16	1.2								6.8										8.0
	17			2.2												5.3				7.5
	18	0.8									2.9					4.7				8.8
	19																			7.6
	20		1.8		5.6															7.4
(kg)	21									6.2					2.8				9.0	

* Code numbers correspond to those indicated in Table 1

Table 4. Weight of buffalo - 150 kg, - Weight gain - 0.25 kg / day.

Type of Feed	Serial No.	Code No. *												Total Wt (kg)				
		20	19	17	16	18	3	11	21	1	8	4	10		7	2	5	6
F E E D	1		0.3				16.9											17.2
	2										12.0			3.2				15.3
	3	0.4					16.5											16.8
	4		0.7		2.2		14.1											17.0
	5		1.2							5.0	9.5							15.6
	6	0.1				15.5												15.6
	7		1.5										11.0		6.7			13.3
	8		2.0		5.2									3.2				11.4
	9		0.5				12.9	4.6										18.0
	10	0.6					11.7	5.1										17.4
M	11		1.8										9.8	0.9				12.5
	12		2.7											2.5		2.7		8.0
I	13							15.8							3.6			19.4
X	14										13.7					0.4		14.0
T	15		0.1			15.6												15.7
U	16				7.5													15.6
R	17			10.2											8.1			16.4
E	18	2.1		11.3											6.2		0.3	13.7
S	19											10.0			6.2			16.3
(kg)	20		0.8										14.4					15.2
	21	1.0										13.3						14.3
	22		2.6														3.5	6.0

* Code numbers correspond to those indicated in Table 1

Table 5. Weight of buffalo - 150 kg - Weight gain - 0.5 kg / day.

Type of Feed	Serial No	Code No. *											Total				
		20	19	16	18	3	11	21	1	8	4	10	7	2	6	22	Wt.(kg)
F E E D	1				20.3									3.4			20.7
	2		1.2			7.2						5.6					14.0
	3	1.5				6.6						5.2					13.2
	4	2.2		1.8								6.4					10.4
	5		2.1									7.1		8.5	0.9		10.1
	6			6.2			7.7										22.4
	7		0.1		20.5									7.7	1.2		20.6
	8						2.7							10.7			21.7
	9			9.9										8.6			20.6
	10							9.2						8.2			17.8
M I X T U R E S (kg)	11								13.2								21.4
	12		1.4							7.2		5.2		8.1			13.7
	13										10.3			6.7			18.4
	14										5.8						21.6
	15						9.2		5.6		12.7			3.3			21.6
	16					9.2				8.9				9.0			27.1
	17		2.0											7.5		12.4	21.9
	18	2.2												6.7	3.7		12.6
	19	0.3			17.5		3.4										21.2
	20		0.4		13.3						6.8						20.4
	21					13.0					3.9						21.0
	22	0.7						9.7						4.2			17.0
	23	1.7									6.5		4.7	6.5			12.8

* Code numbers correspond to those indicated in Table 1

Table 6: Weight of buffalo - 250 kg - Maintenance.

Feed compo nent.	Serial No	Code No. *																		Total Wt. (kg)
		19	20	17	16	18	3	15	11	21	1	8	10	7	2	5	6	12	22	
F E E D M I X T U R E S (kg)	1		2.1				10.6													12.7
	2		3.4					8.6												12.0
	3	2.7					7.2													9.9
	4		3.6		7.5								0.2							11.3
	5		4.2														2.9			7.0
	6																			12.3
	7																			11.7
	8		4.1																	7.4
	9			9.3								1.6								11.7
	10		3.0																	12.3
	11		3.5																	5.7
	12																			11.3
	13									1.1										12.5
	14			1.6							3.4									11.7
	15																			11.7
	16		3.2			5.2														12.7
	17					4.4														8.2
	18	3.8																		10.1
	19		1.8								13.1									14.9
	20		3.7			6.3														10.7
	21		3.5			6.3				1.4							9.7			11.2
	22																			11.2
	23		4.2																	8.2
	24		3.4			5.4							2.9							11.7

* Code numbers correspond to those indicated in Table 1

Table 7: Weight of buffalo - 250 kg, - Weight gain - 0.25 kg/ day.

Type of Feed	Serial No.	Code No. *																	Total Wt.(kg)
		20	19	17	16	18	3	15	11	21	1	4	9	7	2	6	12	22	
F E E D			0.5				22.0												22.5
	2		1.7		6.2		13.8												21.7
	3		2.9		10.1								3.3						16.3
	4		4.1										2.0			4.5			10.6
	5							20.2							5.1				25.3
	6		2.6	18.0	1.1														21.7
	7		2.4		14.0										4.0				20.3
	8		1.1									18.7							19.8
	9								12.3	11.8				1.0					25.1
	10	1.3				4.0			18.3										23.6
M I X T U R E S	11		0.5					3.9				16.7							26.1
	12		2.3	17.1				2.9											22.3
	13								8.9						8.8				17.7
	14				9.6										10.8				20.4
	15	2.4			7.2		9.4										1.8		19.0
	16		2.2					15.0											19.0
	17					20.2		0.1											20.3
	18		4.3												2.0			7.7	13.9
	19									27.1					0.1				27.2
	20	0.6					21.3												21.9
(kg)	21		0.9		3.8					21.0							2.5		25.7
	22		3.6		7.4														13.5
	23						20.2								2.2				22.4

* Code numbers correspond to those indicated in Table 1

Table 8: Weight buffalo – 250 kg, Weight gain – 0.5 – kg/day.

Type of Feed	Serial No	Code No. *												Total WT. (kg)				
		20	19	17	16	18	3	11	21	1	8	4	10		7	2	6	12
	1		0.3					23.4							6.5			30.2
	2	1.4												1.0				23.9
	3		3.9				21.5							5.9		2.3		12.6
	4							22.3							7.5			29.8
	5		1.7									22.1	0.0					23.8
	6		1.7			14.6					8.8							25.1
F	7		2.9									10.0	4.2					17.1
E	8				10.6										13.9			24.5
E	9										14.2				11.2			25.4
D	10		4.4	1.8													4.9	11.1
	11		2.9	12.6									4.3					19.8
M	12	0.8				23.1												23.9
I	13								9.9						11.6			21.5
X	14	3.3							7.2				4.0					14.5
T	15	4.5		4.9													3.0	12.4
U	16		2.7			14.7										2.7		19.4
R	17		0.7				25.2											26.8
E	18								0.8	27.6					0.9			31.2
S	19		1.5							5.6	17.8				2.8			24.9
(kg)	20	3.4											9.4	2.9				15.7
	21	4.4						3.4									3.6	11.4
	22		2.3									15.5			3.5			21.2
	23						22.3								4.3			26.6

* Code numbers correspond to those indicated in Table 1

Table 9: Amount of feeds added to mixtures, on dry matter basis.

Feeds	Range, %	No. of Mixtures
Treated straw	3 - 33	101
Untreated straw	1 - 75	165
NB 21	12 - 59	38
Natural grass, road	1 - 47	63
Br. brizantha	23 - 86	52
PGN	20 - 82	37
Nat. Grass, paddy	1 - 38	15
Hamil	1 - 69	60
VRI 435	2 - 46	23
Bana	26 - 37	26
Glyricidia	2 - 23	69
Banana	1 - 65	170
Cassava leaf	3 - 18	16
Erythrina	1 - 22	33
Ipil-IPil	3 - 23	26
Wild sunflower	5 - 47	8
Jak leaf	45 - 40	4
Jak seed	2 - 84	10
Br. Mutica	18 - 73	32
Green panic	2 - 76	26
Guinea "A"	2 - 51	30
Guatamala	30 - 89	15

DETOXIFICATION OF CASSAVA FOLIAGE AND ITS UTILIZATION AS A WATER BUFFALO FEED

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Abstract: Studies were conducted at the Philippine Carabao Center, Ubay, Bohol to evaluate the biological and economic potentials of cassava foliage (CSF) detoxification and utilization as a feed for water buffalo. Analysis showed that fresh CSF contains hydrocyanic acid (HCN) ranging from 86-186 ppm (fresh basis). Wilting or drying reduced ($P<0.01$) HCN content below the biologically acceptable level of 80 ppm (dry basis) for low and medium HCN varieties, but not for high HCN variety which was reduced only by ensiling. Silage pH (3.5-4.5) and physical appearances indicated that cassava foliage is a good silage material.

Buffaloes fed with different levels of ensiled cassava foliage showed that average daily gain (ADG) increased ($P<0.01$) from 0.74 kg in control (0% CSF) to 0.86 kg with 50% CSF in roughage. Feeding CSF at 75% of roughage did not improve animal performance. Dry matter intake was highest at 25% CSF feeding with 2.35% of body weight. This reduced to 2.28% at 50% CSF and 2.14% at 75% CSF. Feed intake reduction at high CSF silage feeding could be attributed to increased HCN ingestion. Sulphur supplementation for HCN detoxification increased ($P<0.05$) dry matter intake in animals fed 75% CSF. An ADG of 1 kg was attained, which could be attributed to the increased sulphur content of the diet due to increased concentrate supplementation. Comparative income analysis of different cassava-based production systems showed that income increased from ₱15,360 for cassava without defoliation to ₱22,160 for cassava with defoliation and ₱36,775 for cassava with livestock integration. Therefore, income in cassava-based farming can be maximized by livestock integration.

Keywords: Cassava foliage, cassava defoliation, cassava detoxification, ensiling, buffalo.

Introduction

Cassava, *Manihot esculenta* Crantz, is considered to be one of the most efficient crops in converting sunlight into dry matter. Known as a poor man's crop, it could be grown under marginal soil conditions and is usually planted in areas where other crops have low productivity. As of 1997, the area planted with cassava in the Philippines (226,500 hectares) ranked sixth behind rice, coconut, corn, sugarcane and banana (BAS, 1998). Central Visayas ranked fifth among the cassava producing regions with 20,393 hectares planted.

Cassava tuber has been traditionally used as a source of carbohydrate in human food, animal feed and for industrial purposes. It has a long maturity period of about 10 to 12 months, which makes it less competitive in terms of productivity compared to short duration cereal grains. On the other hand, the long period of maturity allows the utilization of its foliage for other economic purposes. Cassava foliage (CSF) is one of the by-products in cassava farming, the potential of which has not been fully exploited. A study by Salces *et al.* (1996) showed the potential of utilizing CSF in ruminant feeding. Defoliation of 50% of the foliage, five and seven months after planting gives a potential yield of five tons dry matter (DM) without affecting its tuber yield.

However, the presence of toxic hydrocyanic acid (HCN) limits the use of CSF in animal feeding. The cyanide level in leaves could reach a maximum of 2466 ppm in some varieties and a minimum of 189 ppm in other varieties. It has been reported that chopping followed by sun drying is one of the most effective methods of detoxification. McCarty *et al.* (1971) also reported that ensiling reduced the HCN content of sorghum plants from 125.46 to almost zero ppm. Present evidence suggests that feeding cassava with 20-80 ppm HCN does not produce any ill effects in animals (Devendra, 1977).

Objectives

This study was conducted to determine the biological and economic potentials of utilizing cassava foliage for water buffalo feeding. Specifically, the study was aimed at attaining the following objectives:

- (a) to determine the detoxification methods that can reduce cassava foliage HCN content to biologically acceptable level;
- (b) to determine the effect of different levels of cassava foliage feeding on liveweight performance of growing buffaloes;
- (c) to evaluate the effect of sulphur supplementation on liveweight performance of buffaloes fed high levels of CSF; and
- (d) to determine the profitability of cassava defoliation and livestock integration in cassava based farming.

Materials and Methods

Study 1. Evaluation of different methods of HCN detoxification in CSF

Experimental design and analysis

Three selected cassava varieties representing low, medium and high HCN contents and which are popularly grown in Bohol were evaluated for HCN content and HCN detoxification. Standing cassava crops were defoliated four to five months after planting and the foliage was used for HCN analysis and detoxification experiments. The effects of processing such as wilting, drying and ensiling on HCN content were evaluated. In addition, the effects of carbohydrate sources, such as molasses and cassava meal as well as Napier grass, on silage quality and HCN content of cassava foliage based silage were evaluated. The experiment was laid out in a 3 x 7 factorial experiments in randomized complete block design (RCBD) as follows:

<i>Factor A – Varieties</i>	<i>Factor B - Processing methods</i>
A1 – Lakan , low HCN	B1 Fresh (control)
A2 – VC1, medium HCN	B2 Wilting
A3 – Datu , high HCN	B3 Drying
	B4 Ensiled CSF (ECSF)
	B5 Ensiled CSF + 25% grass (ECSF/G)
	B6 Ensiled CSF + 5% cassava meal (ECSF/CSM)
	B7 Ensiled CSF + 5% molasses (ECSF/M)

Hydrocyanic acid content and silage pH levels were statistically analyzed using Analysis of Variance (ANOVA) of Statistical Analysis System (SAS, 1985) following a 3 x 7 factorial randomized complete block design (RCBD) model. Data on hydrocyanic acid contents of fresh and processed cassava foliage were transformed using logarithmic transformation.

Study 2. Performance of buffaloes fed with different levels of ensiled CSF

Experimental design and feeding

Twenty-four (24) two to three year old island born male buffaloes weighing 175-300 kg were used in the experiment. Roughage and concentrates were given in the ratio of 75:25 percent of the dry matter (DM) offered. The roughage component was composed of ensiled cassava foliage and napier grass. Ensiled cassava foliage was incorporated at different levels in the roughage diet in the following ratio on DM basis:

- T1 - 100% Napier (0% ECSF)
- T2 - 75% Napier + 25% ECSF
- T3 - 50% Napier + 50% ECSF
- T4 - 25% Napier + 75% ECSF

Twenty-four feeding stalls were divided into six blocks with four stalls per block. Buffaloes were divided into six groups according to weight. Animals in each block were randomly allotted to four dietary treatments following RCBD. Feeds were given at the rate of 2.5% of body weight (BW) with a 10% allowance to provide optimum dry matter intake for eleven weeks feeding.

Data collection and analysis: Initial and final weights of the animals were determined from the average of three consecutive weighings. Feed offered were weighed while feed refusals for each animal were collected and weighed daily. Samples of feeds offered and refused (100 grams) were collected daily and pooled weekly for nine weeks. Weekly samples were pooled and analyzed for dry matter (DM), crude protein (CP), calcium (Ca), phosphorus (P) and cell wall components: neutral detergent fibre, acid detergent fibre, hemicellulose, cellulose, lignin and acid insoluble ash at DA-RFU 7 and Ubay Stock Farm Feed Laboratory using the procedures of Goering and Van Soest (1970). Calcium and phosphorus contents were analyzed by volumetric and colorimetric methods, respectively (AOAC, 1975). Data were analyzed following RCBD model using PROC GLM (SAS, 1985). Linear, quadratic or cubic effects of levels of ensiled CSF feeding were determined by orthogonal polynomials.

Study 3. Effect of sulphur supplementation on dry matter intake and growth of buffaloes fed with high levels of ensiled cassava foliage

Performance of animals fed 50% and 75% ensiled CSF with and without sulphur supplementation was evaluated in this experiment. Sixteen out of 24 animals used in study 2 were selected and blocked according to weight. The animals were randomly allotted to 2 x 2 factorial experiment as follows:

Factor A. ECSF level

- A1 - 50% ECSF
- A2 - 75% ECSF

Factor B. Sulphur Supplementation

- B1 - Without Sulphur
- B2 - With sulphur (2 gm/kg/CSF)

Sulphur in the form of MnSO_4 (feed grade with 95.64% purity) was incorporated in the concentrate feed at the rate of two grams sulphur per kilogram of CSF offered. Feeding was done following the procedure used in Study 2 for six weeks. Data collected were liveweight change, feed intake, nutrient intake and feed efficiency. Data were analyzed following a model with two levels of CSF and two levels of sulphur with interaction in RCBD using PROC GLM (SAS, 1985).

Economic analysis

The potential income from cassava defoliation, CSF feeding and livestock integration in cassava-based production system was determined.

Results and Discussion

Study 1. Evaluation of different methods of HCN detoxification in CSF

Cassava foliage composition

The component of cassava foliage dry matter at 50% defoliation was determined using a 10-plant samples. Leaf ranged from 60-66 %, 12-15% stem and 20-28% petiole of the foliage dry matter.

Crude protein (CP) content analysis showed that leaves have CP contents ranging from 22.8 - 26.9%, while stem and petioles have 6.4 - 8.3%. Whole foliage has CP contents ranging from 16.6 - 19.6%. Variability in CP content of cassava foliage was also reported in several publications. Scholz (1972) cited by Devendra (1977) revealed that cassava foliage has 10 - 12% CP content. Montaldo (1977) reported that 18.2% crude protein was present in cassava foliage. The differences could be attributed to several factors such as parts of the plant analyzed, leaf to stem ratio, soil, fertilization and variety. Nevertheless, it has been observed that CP content is indeed high which shows the potential of cassava foliage either as the sole roughage or as a supplement in animal feeding.

Hydrocyanic acid content of different foliage components was determined using a fresh foliage sample. Results showed that in all varieties, the leaf had generally higher HCN content (fresh basis) than the stem and petioles except for the VC1 variety. The HCN content in leaves ranged from 86 ppm (VC1) to 224 ppm (Datu). The HCN in stem ranged from 34 ppm (Lakan) to 145 ppm (Datu), while petioles have 86 -129 ppm. The whole plant HCN content ranged from 86 ppm (VC1) to 186 ppm (Datu), while Lakan had 92 ppm (Table 1). These results indicated that feeding fresh cassava foliage can cause possible toxicity due to high HCN levels in leaves and whole foliage, which are above the tolerable level of 80 ppm (Devendra, 1977).

Table 1. Contents of foliage dry matter, CP and HCN in three cassava varieties at 50% defoliation¹.

Parameter	Cassava variety		
	Lakan (UPL Ca 2)	VC1 (CM 323-53)	Datu (UPL Ca 1)
Foliage dry matter component, %			
Leaf	60	66	61
Stem	12	14	15
Petiole	28	20	24
Crude Protein, % of DM			
Leaf	22.8	25.9	26.9
Stem	7.6	7.3	6.4
Petiole	7.34	7.6	8.3
Whole foliage	16.6	19.6	19.4
HCN content, ppm of fresh			
Leaf	108	86	224
Stem	34	86	145
Petiole	86	86	129
Whole foliage	92	86	186

¹Taken from 10 plant samples

Effects of processing on HCN content

Effects of wilting, drying and ensiling on HCN content of Lakan, VC1 and Datu varieties are shown in Figure 1. Results showed that processing reduced ($P<0.01$) HCN content in the three varieties. Wilting and drying reduced HCN content to biologically acceptable levels (below 80 ppm DM basis) for Lakan and VC1 varieties but not for Datu variety. Ensiling reduced HCN content lower than 80 ppm for all varieties including high HCN variety.

The results of drying and ensiling agree with the findings of McCarty *et al.* (1971) and Wheeler and Mulcahy (1989), but disagree with the findings of Kategile *et al.* (1988). In this experiment, ensiling proved to be the more effective method of HCN detoxification. Ensiling reduced HCN to an undetectable level for low HCN varieties and to a biologically acceptable level of below 80 ppm for high HCN varieties, respectively. Pre-wilting of material for ensiling removed most of the free HCN because cyanide present as cyanohydrin is converted to gas above 28°C. Furthermore, ensiling removed intact or bound HCN because the ensiling process caused disintegration of the intact glycosides *via* marked cell disruption, drop in pH and intense heat

generation. Drop in pH inactivates the linamarase enzyme responsible for HCN production (Cooke and Maduagwu, E.N. 1985).

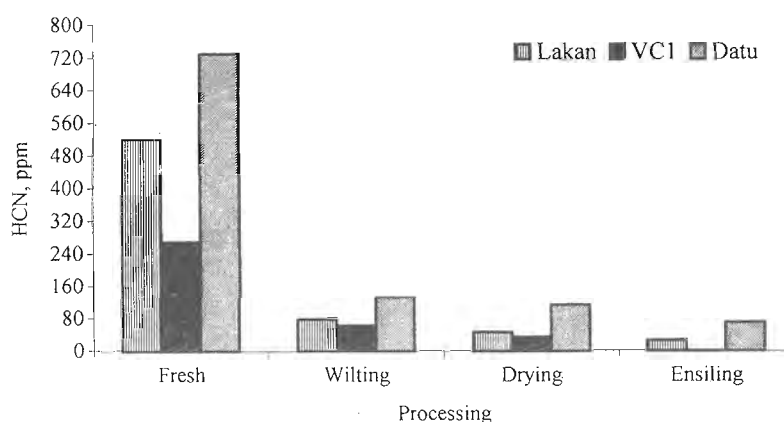


Fig. 1 Effect of processing on HCN content of cassava foliage (dry matter basis)

The pH of ensiled cassava foliage ranged from 3.5 - 4.5. This and the physical characteristics of the different silages in terms of appearance and smell indicated that cassava foliage is good silage material (Table 2).

Table 2. The pH content of cassava foliage in three varieties after ensiling.

Variety	Ensiling method				MEAN
	ECSF	ECSF/G	ECSF/CM	ECSF/M	
Lakan	4.3	4.4	4.3	3.9	4.2 ^a
VC1	4.5	3.5	3.8	3.7	4.0 ^b
Datu	3.6	3.8	3.6	3.5	3.7 ^c
Mean	4.1 ^a	4.0 ^a	3.9 ^{ab}	3.7 ^b	

Means in rows or column with the same superscript were not significantly different.

In practice, cassava foliage is available only at a certain growth stage of the plant, i.e. at five months (Salces *et al.*, 1996), 8 - 9 months after planting (Scholz, 1972) or within one month before harvest (Data *et al.*, 1983) to make use of the remaining foliage. Therefore, drying or ensiling available forages will not only preserve excess feed resources for future use, but also cause the detoxification of cyanide content.

Study 2. Performance of buffaloes fed with different levels of ensiled CSF

Performances of animals fed increasing levels of ensiled CSF are shown in Table 4. Results showed a quadratic trend in dry matter intake ($P < 0.05$) and average daily gain ($P < 0.01$), but did not effect feed efficiency. Average daily gain (ADG) increased as CSF inclusion increased up to 50% CSF. Average daily gain increased from 0.74 kg (0% ECSF) to 0.79 kg (25% ECSF) and a maximum of 0.87 kg at 50% ensiled CSF. At 75% CSF feeding, ADG decreased to 0.72 kg. This result is contrary to the modeling study by Salces *et al.* (1997) in which an ADG of one kg was attained at 75% CSF feeding. One of the major limiting factors with high CSF feeding was the reduction in dry matter intake from a maximum of 2.36% BW (25% ECSF) to 2.14% BW (75% ECSF) which in turn resulted in lower total digestible nutrients (TDN) and P intake. Daily CP intake (989 grams) and Ca intake (67 grams) at 75% CSF feeding was sufficient to support optimum growth while TDN (3.47 kg) and P intake (22 grams) were deficient (Table 3). Therefore, it could be concluded that the energy and P levels limit CSF-based diet in attaining optimum growth. This limitation was mainly due to a reduced intake at high CSF inclusion rate.

Table 3. Average daily dry matter and nutrient intakes in buffaloes fed different levels of CSF.

Parameter	ECSF level			
	0% ECSF	25% ECSF	50% ECSF	75% ECSF
Total digestible nutrients (kg)	3.35	3.62	3.60	3.47
Crude protein (gm)	634	808	923	989
Calcium (gm)	29	45	57	67
Phosphorus (gm)	33	31	26	22

There were no clear indications of factors causing intake reduction at high CSF level. Although analysis of HCN content in silage showed undetectable levels, traces of HCN could be present in the silage moisture, which is not detected by the sodium picrate assay. McCarthy *et al.* (1971) postulated that since HCN is highly soluble in water, some of the HCN may have been absorbed in the silage moisture, which was not detected during analysis. Traces of HCN undetected during the analysis may have been responsible for depressed intake at high CSF inclusion rate. With high levels of HCN in the diet, sulphur has been utilized for HCN detoxification process, causing deficiency of sulphur or sulphur containing amino acid. Reduced feed intake is manifested if there is a sulphur deficiency (Stobbs and Wheeler, 1977). Animal performance is expected to decline if there is reduction in feed intake and utilization of sulphur containing amino acid for HCN detoxification.

Table 4. Performance of buffaloes fed different levels of CSF silage for 9 weeks.

Parameter	ECSF level			
	0% ECSF	25% ECSF	50% ECSF	75% ECSF
No. of animals	6	5	6	6
Age in months ^{ns}	28.25	27.63	27.86	26.38
Initial weight (kg) ^{ns}	234.90	233.10	232.40	232.75
Average daily dry matter intake (kg) ^{ns}	5.95	6.19	5.93	5.52
Average daily dry matter intake (% BW) ^a	2.27	2.36	2.28	2.14
Final weight (kg)	281.33	282.94	287.00	278.08
Average daily gain (kg) ^b	0.74	0.79	0.87	0.72
Feed efficiency ^{ns}	8.30	7.83	6.89	7.80

^a Significant quadratic effect, ($P < 0.05$)

^b Significant quadratic effect, ($P < 0.01$)

^{ns} No significant differences, ($P > 0.05$)

Study 3. Effect of sulphur supplementation on dry matter intake and growth of buffaloes fed high levels of ensiled cassava foliage

Performance of buffaloes fed high levels of ensiled CSF with and without sulphur supplementation showed the relative performance through CSF level and sulphur interaction ($P < 0.05$) in dry matter intake. Sulphur supplementation at 75% CSF feeding increased feed intake from 2.15% BW to 2.22% BW but reduced at 50% CSF feeding from 2.19% BW to 2.10% BW. However, sulphur supplementation did not significantly affect liveweight performance and feed efficiency of animals. At 50% and 75% CSF feeding, average daily gains were 0.90 - 0.94 kg and 1.01 - 1.02 kg, respectively. Feed required per kg liveweight gain ranged from 6.41 to 7.30 kg (Table 5).

The increase in dry matter intake with sulphur supplementation at 75% CSF feeding indicates that sulphur aided in the HCN detoxification process, as source for thiocyanate formation and subsequent excretion. However, the process did not increase the liveweight gain of animals. Liveweight gain of one kilogram per day was already attained and could be the optimum performance. In the metabolism model by Salces *et al.* (1997), it was projected that an ADG of

Table 5. Performance of buffaloes fed CSF silage with and without sulphur supplementation.

Parameter	50% ECSF		75% ECSF	
	no Sulphur	with Sulphur	no Sulphur	with Sulphur
Number of animals	4	4	4	4
Initial weight (kg)	291	292	290	294
Average daily dry matter intake (kg) ^{ns}	6.57	6.34	6.47	6.32
Average daily dry matter intake as % of BW*	2.19	2.10	2.15	2.22
Final weight (kg) ^{ns}	322	325	327	330
Average daily gain (kg) ^{ns}	0.90	0.94	1.01	1.02
Feed efficiency ^{ns}	7.30	6.74	6.41	6.67

*Significant CSF level x sulfur interaction, (P<0.01)

^{ns} No significant differences, (P>0.05)**Table 6.** Comparative income analysis for one hectare cassava production with and without defoliation.

Economic parameter	Unit value ¹	Tuber production	Defoliation*		
			A	B	C
Income, P**					
Gross income from tuber ²	1.10	27,500	27,500	27,500	27,500
Gross income from CSF ³	0.40		1,600	4,800	3,000
Total income		27,500	29,100	32,300	35,500
Cost, P					
Labour					
Land preparation (17 MAD)	160.00	2,720	2,720	2,720	2,720
Planting (4 MD)	80.00	320	320	320	320
Inter row cultivation (4 MAD)	160.00	640	640	640	640
Fertilizer application (2 MD)	80.00	160	160	160	160
Tuber harvesting (16 MD)	30.00	1,280	1,280	1,280	1,280
Defoliation (5 MD)	80.00	-	400	800	1200
Planting materials (20,000 pcs)	0.10	2,000	2,000	2,000	2,000
Fertilizer (6 bags)	325.00	1,950	1,950	1,950	1,950
Interest on capital (%/year) ⁴	24	1,870	1,870	1,870	1,870
Land rental	1,200.00	1,200	1,200	1,200	1,200
Total Cost		12,140	12,540	12,940	13,340
Net Income, P		15,360	16,560	19,360	22,160
Percent change compared to tuber production only			7.81	26.04	44.27
Income sensitivity					
Max reduction in tuber yield				14.55%	24.73%

*Cassava foliage (CSF) harvesting regimes

A - Defoliation within one month before tuber harvest with potential CSF yield of 1 ton DM/ha or 4 tons fresh matter (present study)

B - Defoliation at 8th months after planting (MAP) and during harvest with potential CSF yield of 3 tons DM/ha or 12 tons fresh (Scholz, 1972 as cited by Devendra, 1977)C - Defoliation at 5th MAP, 8th MAP and at harvest with potential yield of 5 tons DM/ha or 20 tons fresh (Salces *et al.*, 1996)

**Peso - Dollar exchange rate (₱40.00 = 1 US \$)

¹Farm price²Potential yield of 25 tons tuber/ha³Based on potential yield of defoliation system⁴Financing by the processing plant

MD - man day, MAD - man and animal day

one kg could be attained at 75% cassava foliage feeding together with 2 kg of concentrate supplementation. In the first feeding trial, the low ADG attained can be attributed to the low TDN intake, one of the limiting factors affecting animal performance. In this feeding trial wherein smaller animals were used (232 kg initial weight), concentrate supplement averaged only to 1.5 kg/head/day. In the second feeding trial, the initial weight of the animals averaged to 294 kg, resulting in higher actual concentrate volume of approximately 2 kg per head per day. The higher concentrate volume increased TDN and P intake. Similar level of supplementation was predicted in the model by Salces *et al.* (1997) which could result in an ADG of 1 kg. Therefore, sulphur supplementation may not be needed when feeding high level of ensiled CSF, if energy and sulphur containing amino acid were sufficiently given in the diet.

Economic analysis

Cassava production subsystem

The cost and return on a per hectare basis of cassava production without defoliation and with different defoliation practices was analyzed (Table 6). The net income from cassava production without defoliation was ₦15,360 from one crop year, based on the potential tuber yield of 25 tons per hectare and current farm price of ₦1.10/kg tuber. The income increased to ₦16,560/ha for defoliation at harvest (A), ₦19,360 for defoliation at 8th MAP (B) and ₦22,160 for defoliation at 5th MAP (C).

Livestock production subsystem

The cost and return structure on per kg liveweight basis for feed rations without CSF (napier and concentrate only) and with increasing amounts of CSF (25%, 50% and 75%) were examined. At 0% CSF, the net income over feed cost was ₦18.22/kg which increased to ₦20.41/kg for 25% CSF, ₦20.99/kg for 50% CSF and ₦22.19/kg for 75% CSF. These results correspond to 12.02%, 15.20% and 22.28%, respectively, increases in net income over feed cost relative to a non-CSF feed ration. Considering the total cost, where it was assumed that feed cost comprised 75% of total production costs, the net income over total production cost amounted to ₦8.63, ₦11.55, ₦12.31 and ₦13.92 for 0%, 25% 50% and 75% CSF, respectively (Table 7).

Table 7. Income analysis of cassava foliage (CSF) utilization as buffalo feed.

Economic parameter		Value				
		Per kg	100:0	75:25	50:50	25:75
Income, ₦	Income per kg LWG	47.00	47.00	47.00	47.00	47.00
Cost/kg feed	Concentrate (25% of DMI)	7.00	1.75	1.75	1.75	1.75
	Roughage (75% of DMI)					
	Napier ¹	1.36	1.02	0.77	0.51	0.26
	CSF ¹	2.04	0.00	0.38	0.77	1.15
	Total cost/kg mixed feed		2.77	2.90	3.03	3.16
	Feed efficiency ²		10.39	9.18	8.60	7.85
	Total feed cost/kg gain		28.78	26.59	26.02	24.81
	Income over feed cost		18.22	20.41	20.99	22.19
	Income over production cost ³		8.63	11.55	12.31	13.92
Income	Increase in CSF Cost					40.80%
Sensitivity	Decrease in LWG					16.30%

*Roughage is 75% of dry matter intake (DMI)

¹Based on 85% dry matter and 75% roughage of feed offered

²Kg feed consumed per kg liveweight gain (LWG) based on the result of the feeding trial expressed at 85% dry matter

³Computed based on the assumption that feed cost is 75% of the total production cost

Cassava/livestock integrated production system

Comparative incomes and costs for cassava with and without defoliation and cassava with livestock integration are shown in Figure 2. The net income increased from ₱15,360 in cassava without defoliation to ₱22,160 in cassava with defoliation (5 MAP) and ₱36,775 for cassava with livestock integration (Table 8). Therefore, income from cassava based farming is maximized by integrating livestock production.

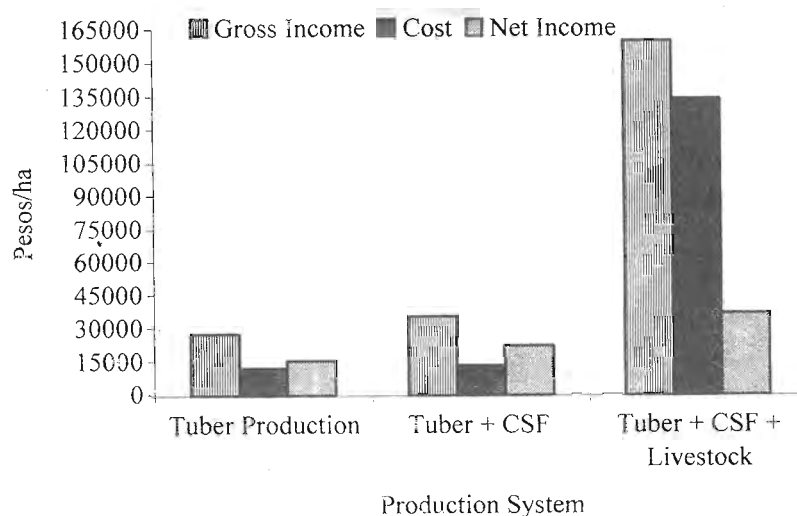


Fig. 2. Comparative income from different production systems in cassava-based farming

Table 8. Income analysis of livestock integration in cassava production system.

Economic parameter		Income sources		
		Cassava	Livestock	Total
Income, ₱	Cassava tubers (0.8ha)	22,000	75,200	22,000
	Gross sales of 4 90-day fattened animals ¹		37,600	75,200
	Gross sales of 2 120-day fattened animals ¹		22,500	37,600
	From work animal (₱150/day for 150 days)		2,400	22,500
	increase value of work/breeding animal			2,400
	Total Income	22,000	137,700	159,700
Cost	Cassava production cost (0.8 ha)	8,752		8,752
	Defoliation cost		1,605	1,605
	Napier maintenance cost (0.2 ha)		700	700
	Fattening stocks ²		72,000	72,000
	Feeds		8,400	8,400
	Land rental	960	240	1,200
	Depreciation cost ³		1,000	1,000
	Interest on capital in fattening operation ⁴		5,628	5,628
	Opportunity cost of family labor ⁵		21,000	21,000
	Opportunity cost of fixed capital ⁶		2,640	2,640
Total Cost		9,712	113,213	122,925
Net Income		12,288	24,487	36,775

¹At ₱ 47 per kg liveweight

²Acquisition cost of ₱ 40 /kg liveweight

³Cost of fattening house and silo at ₱ 10,000 with 10 years life span

⁴Based on cooperative financing rate of 7% in 6 months

⁵At ₱ 37,50/day for 260 days in fattener and ₱ 75.00/day for 150 days from work animal

⁶12% of fixed capital cost (₱10,000 for work animal, ₱2,000 for napier pasture and ₱10,000 for building)

Conclusion and Recommendations

Studies revealed biological and income potential of cassava defoliation, detoxification and feeding up to 75% in the roughage diet. Based on the results of the studies conducted, the following recommendations were made:

- Cassava foliage must be processed before feeding
- Fresh cassava foliage from sweet varieties like Golden Yellow, Lakan, etc. should be chopped and wilted for three to four hours before feeding
- Preservation and detoxification by drying is recommended for low and medium HCN varieties, while ensiling is required for high HCN varieties like Datu and varieties with unknown HCN levels, to detoxify HCN content;
- Further studies need to be undertaken, particularly on the long-term effect of feeding CSF to breeding animals, that stay longer in the farm or in dairy animals where high protein feed is needed.

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OIL PALM BY-PRODUCTS AND UREA MOLASSES MINERAL BLOCKS AS FEED RESOURCES FOR BUFFALOES IN MALAYSIA

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Abstract: The National Agriculture Policy of Malaysia supports the commercialisation of ruminant production through integration with plantation crops as well as through feedlot operations. For this purpose, alternative feed resources need to be developed. This paper describes several by-products of the oil palm industry, the potential availability and their utilisation in ruminant feeding. A number of processing techniques have been developed to enhance their utilization and improve their feeding value. Studies have been conducted to determine the chemical composition of the oil palm by-products and the levels of inclusion in ruminant rations. Economic formulations that have been tested on swamp buffaloes in feedlots gave average daily weight gains of nearly 0.6 kg/day and a feed efficiency of 9.0. Two year-old buffaloes raised on native grasses in oil palm plantations showed weight gains of 0.55 kg/day as compared to 0.36 kg/day with 3 year-old buffaloes raised in open pasture. UMMB when used as a feed supplement enhanced the utilisation of poor quality roughages. Rearing of swamp buffaloes in oil palm plantations utilising by-products and crop residues, particularly of the oil palm industry offers a tremendous potential for beef production in Malaysia.

Keywords: Buffalo production, feed resources, crop/stock integration, oil palm by-products, UMMB.

Introduction

There has been an alarming decline in the buffalo population in Malaysia over the last three decades. Between 1988 and 1998, the percentage change in the population is - 31.1 %. Factors contributing to the decrease in population were the displacement of the buffalo with machinery for draught power in the paddy fields, low multiplication rate and labour shortage. The problem was aggravated further by high slaughter rates and inefficient husbandry practices. Relocating the buffaloes to big farms where multiplication programs can be conducted is one of the approaches to increase the population. The contribution of buffaloes in local beef production is secondary to cattle, both providing a self-sufficiency level of 16.5 %.

Improvement in Buffalo Production System

The National Agriculture Policy (NAP) 1992 - 2010, emphasises commercial production in all sectors of agriculture production. Sustainable agriculture production needs to have economy of scale, based on the efficient use of resources. It has to shift from the current small-holder based farming system to commercial operation, with the involvement of entrepreneurs and corporate sectors. The NAP supports the ruminant production through integration with plantation crops as well as through feedlot operations. Alternative and sustained feed resources are therefore needed for buffalo production. One such feed resource is in the oil palm industry where adequate amounts of crop residues and by-products are available to meet the nutritional needs of buffaloes in the country.

Oil-palm and its By-products

Oil palm, *Elaeis guineensis*, is an important crop of Malaysia. In 1997, the total area under oil palm was 2,819,316 ha, an increase of 3.4% over the previous year. The total production of crude palm oil (CPO), palm kernel and palm kernel oil in the same year was 9,088,728 tonnes, 2,638,068 tonnes and 1,164,697 tonnes respectively. There are a number of by-products of the oil-palm and these include palm kernel cake (PKC), palm oil mill effluent (POME), palm press fibre

(PPF), oil palm trunk (OPT), oil palm fronds (OPF) and empty fruit bunches (EFB). These materials can be utilized as sources of roughage or energy for ruminants. The potential supply of feed ingredients derived from oil palm, both in the unprocessed and processed forms, is substantial and would likely be able to support a reasonably large population of swamp buffaloes and other ruminants. Many of these by-products need further processing before they can be used effectively. A number of processing techniques have been developed to improve the feeding qualities of these by-products. They include alkali treatment, preservation as silage, steaming under high temperature and high pressure, pelletizing and enzymatic degradation. A research collaboration between MARDI and JICA was established for the development of livestock feeds from agro-industrial by-products of oil palm.

Oil palm fronds (OPF)

OPF is continuously available in the plantation since the palms are regularly pruned. The leaflets contain higher percentages of CP and EE than the petiole. Chipped OPF of about 2 - 3 cm in size can be conserved as silage, which could last for several months when properly stored. The optimum level of OPF silage in fattening rations for swamp buffaloes and beef cattle was 30 to 40 %. Daily gain of swamp buffaloes fed 30 % OPF silage was comparable to that fed 50 % sago meal (Shamsudin *et al.*, 1993). Once dried and chipped OPF can be turned into pellets for ease of storing, packaging and transport. The keeping quality of pelletized OPF has improved with the use of processing techniques.

Oil palm trunks (OPT)

OPT is only available after oil palms are felled for replanting at an age of about 30 years. Chipped OPT (about 2 cm) can be turned into a medium quality feed for ruminants. The maximum level of inclusion for ruminant is 30%. Without any treatment, the DM digestibility of OPT is comparable to rice straw. Its digestibility can be increased from 23.6 to 36.4 % with steaming. With NaOH treatment, its value increases to 54 – 62% which is equivalent to that of tropical grasses (Abu Hassan, 1995).

Palm press fibre (PPF)

PPF is a fibrous by-product of crude oil extraction of the mesocarp. The ME value is low (Table 1) and it has a lower digestibility (about 22.3 %), which limits its inclusion in ruminant diets to 20 % only (Table 2). Buffalo farmers operating in the vicinity of oil palm mills could utilize PPF to reduce the cost of feeding. It can be fed fresh, or ensiled in drums for longer storage. At higher level of inclusion, the use of PPF could result in bolus formation and impairment of rumen activity.

Empty fruit bunches (EFB)

EFB are the materials that remain after the fruits have been stripped off the fruit bunches, following the steaming process at the oil palm mill. The content of NDF and ADF in EFB were 81.8 and 61.6 respectively. Attempts at utilizing these materials as animal feeds through irradiation and substrate culture have met with limited success.

Palm kernel cake (PKC)

In terms of commercial value, PKC is the most important oil palm by-product. It is obtained from oil palm kernel after the oil has been extracted. Two methods of extraction process are being used i.e. by expeller pressed and solvent extraction. PKC contains high fibre with ADF of 31.7 %. The Cu content is between 20 - 30 ppm.

Palm oil mill effluent (POME)

This is the residue left from the purification of the crude palm oil (CPO). POME is usually utilized as organic fertilizer in crop cultivation and to a small extent as a low quality feed for ruminants. Retardation in rate of growth and skeletal mineralization had been observed when POME was fed at 100 % level in dairy cattle. Supplementation with protein, energy and mineral is necessary.

Table 1. Chemical composition of major by-products from palm oil mill.

Parameters	EFB	PPF	POME	PKC-S*	PKC-E **	OPF	OPT
Dry matter (%)	-	86.2	91.1	90.5	91.8	36.4	32.6
Crude protein (%)	3.70	5.9	11.1	17.3	15.3	5.8	2.0
Crude fibre (%)	48.8	48.6	17.0	13.6	15.0	44.8	25.4
Ether extract (%)	3.20	5.8	12.0	5.2	8.9	1.2	0.6
Ash (%)	-	3.3	9.0	4.0	5.0	6.6	3.6
N-free extract (%)	-	36.5	50.5	60.0	55.8	43.3	54.5
Ca (%)	-	0.32	0.70	0.25	0.20	0.55	0.18
P (%)	-	0.27	0.50	0.65	0.52	0.09	0.05
TDN (%)	-	29.8	45.0	73.2	65.4	35.1	46.5
E (M/kg)	-	4.02	6.52	11.15	9.80	4.90	6.76

Note: *S-solvent extracted, ** E-expeller pressed

Table 2. Suggested levels of inclusion of oil palm by-products in ruminant rations

Parameters	Buffalo	Cattle	Sheep/Goats
PKC	50	50	30
PPF	20	15	15
POME	50	50	30
OPT ensiled	30	30	30
OPF ensiled	30-40	30-40	50
OPF pellets	30	30	30

Source: Wong and Wan Zahari (1992)

The Use of Oil-palm By-products for Fattening Swamp Buffaloes in Feedlot

Several formulations have been accomplished for the fattening of buffalo calves using oil-palm by-products, producing high rate of growth with high quality carcass. (Mohd Sukri *et al.*, 1987). A trial was conducted at MARDI to study the growth performance of swamp buffalo in feedlot. In this study, two groups of buffalo bull calves about 10 months of age were fed with two types of complete rations. The diets were based on palm oil mill by-products, namely PPF, PKC and palm oil sludge (POS). Cassava chips was used as an energy source in ration 1 mainly to replace a portion of PKC and to reduce cost. Ration 2 was formulated totally from by-products of palm-oil mills (Table 3). The growth performance of the buffaloes was comparable in both rations with the LWG of about 0.59 kg/day. Thus, cheap rations for fattening buffalo can be formulated wholly from palm oil-mill by-products without the need for supplementing additional source of energy. In another study, the substitution of PKC with a substantial amount of sago meal had reduced the feed cost and back fat thickness in swamp buffaloes (Shamsudin *et al.*, 1993). (Table 4). The ADG of swamp buffalo supplemented with PKC was 0.66 kg / day as compared to 0.39 kg/day from those raised on open pasture (Table 5) (Mohd Sukri *et al.*, 1994). Meat from feedlot animals was more tender, normal in pH and lighter in colour than that from the grazing ruminants (Dahlan *et al.*, 1988).

Table 3. Growth performance of swamp buffaloes in feedlot.

Growth Performance	Ration 1 ⁺	Ration 2 ⁺⁺
Initial body weight (kg)	171.8	173.1
Final body weight (kg)	320.7	319.3
Total body weight gain (kg)	148.9	146.2
ADG (kg/day)	0.59	0.58
Feed intake (kg/day)	5.3	5.3
Feed efficiency	9.0	9.1

+ Content: 20% PPF, 34.5 % PKC, 20 % POS, 20 % cassava chips, 2.0 % urea and 3.5 % min-vitamin premix (Proximate analyses: 14.0 % CP, 22.5 % CF, 9.4 % EE, 11.1 % Ash, 0.2 % Ca and 0.3 % P).

++ Content: 25% PPF, 50.5 % PKC, 30 % POS, 1.0 % urea and 3.5 % min-vitamin premix. (Proximate analyses: 14.8 % CP, 22.1 % CF, 10.4 % EE, 12.3 % Ash, 0.2 % Ca and 0.4 % P).

Integration of Buffaloes under Oil Palm

The integration of livestock in oil palm plantations is in line with the current government's policy to increase food production and reduce food import. With proper management inputs, livestock integration in oil palm plantation not only generates substantial income, but also in many cases increases the oil palm yield. Other than local Kedah-Kelantan (KK) cattle, swamp buffaloes are suitable to be reared under oil palm, because of its adaptability and resistance to diseases. The recommended stocking rate for swamp buffaloes per unit area of 4 ha with the palm age of 4 to 5 years is 2 head; and for 6 years and above is 1 head. Grazing only native grasses in oil palm plantation, two year old buffaloes gained 0.55 kg per day as compared to 0.36 kg per day with 3 year old buffaloes (Liang and Abdul Rahman, 1985). These results were comparable to those reported under intensive farm conditions.

In areas where the ground vegetation has been limiting in forage or has deteriorated due to drought, overgrazing or closed canopy (above 10 years after planting), the use of oil-palm by-products such as OPF and PPF can be considered as source of roughage. The current interest is centred on OPF. With the current low PKC price, animal supplementation programs can be a cost-effective means of improving animal performance. Although integration in plantation has been shown to be technically feasible and economically viable, the adoption rate of this technology is far from satisfactory. The success of swamp buffalo-oil palm mixed farming system is mainly dependent on the grazing management.

Table 4. Growth Performance and carcass characteristics of buffaloes fed PKC and sago meal based ration

	Ration 1	Ration 2	Ration 3	Ration 4
Growth performance				
Initial body weight (kg)	215.6	217.2	215.7	219.38
Final body weight (kg)	324.8	341.8	347.7	363.75
ADG (kg)	0.59	0.58	0.61	0.67
Feed intake (kg/day)	5.30	5.41	5.39	5.20
Feed efficiency	8.98	9.33	8.84	7.76
Carcass characteristics				
Dressing percentage	52.34	54.06	55.48	57.31
Back fat thickness (cm)	0.57	0.77	0.70	0.50
L. dorsi area (cm)	60.37	46.96	47.55	46.15
Fat (% carcass wt.)	11.57	12.99	12.87	12.48
Meat (% carcass wt.)	62.54	57.28	56.89	59.61
Meat:bone ratio	3.29	2.65	2.62	3.12

Rows with different superscripts differ significantly $P < 0.05$, $n:5$

Ration 1: PKC (98%), Sago (0 %), CaCO_3 (1%), salt (1%), Urea (0%)

Ration 2: PKC (72%), Sago (25.0 %), CaCO_3 (1%), salt (1%), Urea (1%)

Ration 3: PKC (48%), Sago (49.5 %), CaCO_3 (1%), salt (1%), Urea (1.5 %)

Ration 4: PKC (23%), Sago (73.0 %), CaCO_3 (1%), salt (1%), Urea (2%)

Table 5. Growth performance of swamp buffalo bull calves under semi-intensive and open pasture system

	Semi-intensive	Open pasture
Birth weight (kg)	29.0	28.3
Weight at 6 months (kg)	126	145
Average total weight gain (kg)	97	117
ADG - pre weaning (kg)	0.56	0.64
Weight at 1 year	249	211
Average total weight gain (kg)	119	82
ADG - post weaning (kg)	0.66	0.39

Urea-Molasses-Mineral Blocks (UMMB)

UMMB is suitable to be used as supplement for buffaloes consuming low quality forages like OPF and PPF, either in feedlots or in grazing situations. The use of UMMB will upgrade the assimilation of nutrient from poor quality forage and roughage and at the same time provide a useful non-protein nitrogen (NPN), energy, mineral supplements and control of gastrointestinal parasites. The advantages of using UMMB over commercial mineral blocks are evident especially in areas where major nutrients are limiting. Several local feedstuffs have been used as components in UMMB making. These include agricultural by-products from oil-palm industries. The methodology of block making and the effect on the performance of several ruminant species have been described (Wan Zahari *et al.*, 1994; Oshibe and Wan Zahari, 1996).

Adequate nutrition is useful for working buffaloes, particularly in stressful condition. Minerals are constantly excreted from the body through the urine, faeces and skin when animals are at work. Hence they require a relatively constant supply of these minerals and this can be met by strategic nutrient supplementation. The use of UMMB for swamp buffaloes is justified especially when the animals are used for haulage in oil palm plantation. Only sodium chloride is supplemented by the farmers for buffaloes used for draught in the estates (Wan Zahari *et al.*, 1985). The stress of draught output, coupled with inadequate nutrition might cause some physiological imbalances that could result in certain metabolic upsets. One example is the occurrence of hysteria, coma and sudden death related to Mg deficiency (Wan Zahari and Wong, 1990). The depression in both appetite and feed intake due to heat stress have been reported.

Conclusions and Recommendations

Double cropping and mechanization of paddy growing has lead to a decline in local buffalo population. These animals, useful for beef and draught power especially in oil palm plantation, have potential attributes that can be exploited to advantage. To achieve maximum return, the system should be based on producing dual-purpose animals, providing draught power while they are still growing and then slaughtering for meat when they have reached maturity. The general production should be along the same lines as that for cattle development programs currently in progress in the country. Rearing swamp buffaloes in oil palm plantations offers tremendous potential for beef production in view of the availability of by-products to be utilized as feeds. Evaluation of complete rations based on local feedstuffs for buffalo production is urgently needed especially if this animal is to be raised for beef production. Besides emphasizing on the integration of buffaloes under plantation crops, exploitation of crop residues and agricultural waste should be optimized, particularly those from oil palm industry. The use of UMMB as supplement is practical for swamp buffaloes utilizing low quality forages and those used for haulage in the plantation environments.

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SYMPOSIUM - II

Nutrition

Discussion

Q. A.N.F. Perera - Microbial protein is very important for production in animals. However, is the microbial protein enough for high producing animals?

A. M.C.N. Jayasuriya - Yes. But still we do not know exactly how much microbial protein is produced in the rumen. The use of PD techniques will help to assess this contribution.

Q. A. Horadagoda - What is the cost of PEG and is its use cost effective?

A. H. Makkar - Some studies carried out in Zimbabwe used 5 g/day, which would cost around US\$ 1. The fact that farmers kept coming back for PEG shows that it was cost effective. A study done in Israel showed an increase in growth in sheep. It was found that 1 g of PEG was adequate for sheep, but 2-3 g was required for cattle. The PEG recommended is a slow release product. Here too the use of PEG was cost effective.

Q. A. del Barrio - What is the minimum level of tannin in the feed that would interfere with the measurement of PEG? There are two tannins, condensed tannin and hydrolyzed tannin. What tannin do you measure in PEG?

A. H. Makkar - The method used is a biological method that cannot differentiate between the two tannins.

Q. M.C.N. Jayasuriya - Is there any possibility that animals can adapt to high tannin levels by altering rumen microbial function?

A. H. Makkar - Ruminants cannot adapt to hydrolyzable tannins.

Q. A. del Barrio - The usage of UMMB is not popular in the Philippines. Farmers do not like to use UMMB, although it is available. Is UMMB being used in Sri Lanka?

A. A.N.F. Perera - It is very popular in Sri Lanka. There is an increasing demand. We have 4 to 5 UMMB production units.

Q. S.K. Ranjhan - Why are the farmers in the Philippines not using UMMB?

A. A. del Barrio - It is not popular because of the urea. Farmers use urea as a fertiliser for crops but not for animals. UMMB is being used in large farms but small farmers do not use it.

Comment. S.K. Ranjhan - The reason for failure in India is that the hygroscopic ingredients make the UMMB soft. When the block is soft the animal bites and eats it and the intake of urea is excessive. Normally, each block is around 5 kg and so there is a danger of over-eating. To overcome this, farmers cut the block into two and feed it for two days.

Comment. M.C.N. Jayasuriya - The low usage of UMMB is not due to the chronological problems. It is due to economic reasons. It is not economical for farmers to use UMMB, because the cost:benefit ratio is low.

MODERN REPRODUCTIVE TECHNOLOGIES: THEIR POTENTIAL APPLICATION FOR IMPROVING BUFFALO PRODUCTION IN ASIA

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Abstract: Population growth, urbanisation and income growth in developing countries are currently fueled by a massive increase in demand for food of animal origin, which is predicted to result in a "livestock revolution" during the next decade. Achieving this through sustainable use of natural resources whilst conserving biodiversity and preserving the environment will require novel approaches at all levels, from the farmers to policy makers, and will inevitably need wide spread but judicious application of new biotechnologies, including those which can improve breeding management and increase reproductive performance.

The relative importance of reproductive efficiency in the overall profitability of buffalo farming varies with the production system. Under many Asian farming conditions the major constraints to reproductive efficiency include climatic, stress, inadequate nutrition, poor heat detection, incorrect timing of mating or artificial insemination (AI), frequent suckling by calves and misconceptions among farmers or breeding management. Practical methods for overcoming these have been developed through research in many countries, but have not been adequately disseminated among the farming communities.

A range of modern reproductive technologies are currently available to livestock producers in developed countries and, as buffalo systems in Asia become more intensive and commercially oriented, the potential to apply these will arise, but will require suitable modification and adaptation. AI will become increasingly important, particularly in the more intensive systems. However, achieving acceptable fertility to AI demands good heat detection and correct timing of service, factors that are more critical in buffaloes than in cattle. The use of progesterone measurement in samples of milk collected at strategic times in relation to AI can be a useful tool in identifying lapses in reproductive management by farmers as well as weaknesses of AI services. Once corrective measures are in place, progesterone assay in a single sample can be used to provide an early pregnancy diagnosis (N-PD) service to farmers, and will help further improve reproductive performance.

Oestrus synchronization has applications in overcoming the problem of heat detection in buffaloes, but has often been misused, resulting in low fertility. Important considerations for success include careful selection of animal, using reliable treatment regimes, avoiding stress and ensuring correct timing of AI. Other technologies such as embryo transfer, sex pre-selection through sperm sorting, and molecular methods based on genetic markers may have future applications under specific improved buffalo production systems. To be effective, however, all modern technologies must be preceded by fundamental improvements in husbandry, feeding, breeding and disease control.

Introduction

The year 2000 will remain an important milestone in life to all of us. At the threshold of the new decade, century and millennium, we are in a period of rapid change and transition, driven by the need to adapt to global trends in demography, agriculture, industry, communications and demands of discerning consumers. Population growth, urbanization and income growth in developing countries are currently fuelling a massive increase in demand for food of animal origin, which is predicted to result in a "livestock revolution" during the next decade (Delgado, *et al.*, 2000).

However, increasing livestock productivity will need to be achieved through the sustainable use of natural resources whilst conserving biodiversity and preserving the environment (Steinfeld, *et al.*, 1999). This will require novel approaches at all levels, from the farmers to policy makers, and will inevitably need widespread but judicious application of new biotechnologies. As scientists engaged in improving livestock production and health in Asia, it is an opportune time to look closely at the technological developments that are taking place in this field, to identify

opportunities for their application in our countries, and to assist our farmers to use them to improve the cost-efficiency and sustainability of present as well as emerging farming systems.

The challenges and Opportunities

The majority of traditional farming systems which have evolved over the past millennium in Asia have used indigenous genotypes which are well adapted to the environment, and can produce (and reproduce) at a level in harmony with the available resources. However, higher demand for livestock products coupled with decreasing farm land and communal grazing areas have necessitated profound changes to traditional farming systems in many regions (Sere and Steinfeld, 1994). Livestock farmers have usually responded to these pressures, particularly in urban and peri-urban areas, by intensifying their production systems (Ghirotti, 1999), often without adequate assessment of the costs to natural resources and long-term sustainability. These emerging farming systems pose a challenge as well as an opportunity to research workers, to develop appropriate methods to optimally utilize the available resources to obtain higher outputs of livestock products (Perera, 1999a). A further aspect that will inevitably become increasingly important during the next decade is the quality and safety of livestock products, which will be dictated by the needs of more discerning consumers and the growing international trade in these commodities.

Meeting these challenges will require interdisciplinary adaptive research, undertaken with the full participation of all stakeholders, including the farmers and their service providers (Abeygunawardena, *et al.*, 1996a). The essential steps involved in such initiatives will include:

- Identification of strengths and weaknesses of the specific production system;
- Formulation and on-farm testing of appropriate improvements and interventions; and
- Extension and dissemination of proven technologies in the form of an integrated package.

Research and development strategies based on this approach have been promoted by international and bilateral donor agencies during the past decade and have resulted in the availability of valuable baseline information on livestock farming systems in Asia, Africa and Latin America (Perera, 1991; Garcia, *et al.*, 1995). The need now is to use this information, together with recent knowledge gained from technological developments in advanced countries, to the benefit of wider farming communities.

The first section of this paper briefly reviews some of the important constraints relating to reproductive efficiency of buffaloes under Asian production systems and draws attention to the basic improvements in reproductive management and related factors that are essential for an efficient production system. The second section discusses the possible applications of modern reproductive technologies to further enhance fertility and productivity. This approach emphasizes the author's firm conviction that most modern technologies will not be applicable if they are not preceded by improvements in the basic aspects of buffalo husbandry (Perera, 1999b).

Constraints to Higher Reproductive Efficiency

The relative importance of reproductive efficiency in the overall profitability of buffalo farming varies with the production system (Perera, 1994) and is influenced by environment, genotypes, scale of inputs and outputs, managerial skills of the farmers, market forces and sociological considerations. Under optimal conditions, a buffalo heifer should attain puberty at an early age, conceive readily to a fertile mating, produce and raise a viable calf, return to oestrus early during the postpartum period and conceive again, and repeat this cyclic process at regular intervals till the end of its productive life. This ensures a harvest of more milk and calves during the lifetime of the animal, through earlier age at first calving and shorter calving intervals. In order to achieve these goals, the following constraints which are often found to operate under rural buffalo farming systems in Asia need to be addressed.

Genotype

The genotype determines an animal's reproductive potential, but the actual performance achieved depends on a host of factors, chief among which are climate, nutrition, management and diseases. Thus a well adapted swamp buffalo cow might have relatively low inherent reproductive capacity but can achieve its full potential under the prevailing conditions, whereas a river buffalo which has been bred for high milk production may be able to reproduce well under mild climatic conditions but will perform poorly if kept under hot and humid conditions (Abeygunawardena, *et al.*, 1996b).

The practical importance of this is the need to match the genotype to the environment. This can be done by either using a genotype that is adapted, or mitigating the adverse effects of the environment by appropriate housing and management, depending on the specific situation.

Nutrition

Poor nutrition in growing heifers delays puberty, while in adult cows it delays the onset of ovarian activity after calving, resulting in long calving intervals (Jainudeen and Hafez, 1987; Qureshi, *et al.*, 1999). Both situations result in economic losses to the farmer. Under tropical grazing systems, the nutritional status of the animal will be influenced by the availability and quality of feed, which in turn is determined by fluctuations in rainfall (Lundstrom, *et al.*, 1982). Other environmental factors such as high heat and humidity can also have important inhibitory effects on reproduction, due to suppression of appetite and feed intake.

The body condition score (BCS) of an animal is a good indicator of its nutritional status, and can be used for determining the adequacy or otherwise of feeding regimes. More sensitive biochemical indices of nutritional status, such as beta-hydroxy butyrate and urea nitrogen in blood, have proved useful under intensive dairy production systems of developed countries, which are based on uniform genotypes and standardized husbandry practices. However, under the highly diverse production systems with different genotypes found in developing countries, such indices have to be interpreted with caution (Whitaker, *et al.*, 1999). On the other hand, progesterone measurement allows accurate determination of when an animal has commenced reproductive activity (Perera and Abeyratne, 1979) and is a good retrospective index of the effectiveness of feeding regimes. It cannot, however, predict how long an animal is likely to remain acyclic, or whether a particular nutritional treatment will be effective in advancing the onset of cyclicity.

Recent research has shown that two of the critical links between nutrition and reproductive functions are possibly the proteins Insulin-Like-Growth Factor-1 (IGF-1) and Leptin (McGuire, *et al.*, 1992; Keisler, *et al.*, 1999). These appear to be the signals that relay information about body reserves to the brain centres that control reproduction. Current research thrusts in this field are focused on possible applications of measuring IGF-1 and Leptin as clinical tools in cattle and sheep, for evaluating the nutritional status of individual animals, for selection of those that are capable of re-establishing earlier reproductive activity postpartum and for adjusting feeding regimes for more efficient productivity (Adam, *et al.*, 1997; Roberts, *et al.*, 1997).

For practical purposes, the important need is to ensure adequate nutritional support for breeding animals, particularly at critical stages of the production cycle. Training farmers to use BCS as a guide for feeding has been effective in Sri Lanka (Abeygunawardena, *et al.*, 1996a). In future, measuring substances such as IGF-1 or Leptin in blood or milk may prove of greater predictive value, but whether such measures will be cost-effective will depend on the development of simple and cheap assay methods.

Breeding management

In extensive systems with free-range grazing where males and females mingle freely, detection of heat and mating is done by bulls and, provided the latter are fertile, results in the best fertility (de Silva, *et al.*, 1985). In more confined systems (*e.g.* tethered grazing or stall-feeding) the detection of heat has to be done by the farmer and mating is either by the use of a stud bull (hand-mating) or by artificial insemination (AI). This introduces the possibility for human error at several stages, beginning with the detection of heat, through the timing of mating, to the whole range of problems associated with AI, such as semen quality and inseminator skill (Alexander, *et al.*, 1997).

A major deficiency in many smallholder buffalo farms is accurate detection of heat and mating of the cow at the correct time. Even in cattle, studies using progesterone measurements have shown that only 40-50 % of ovulations occurring during the postpartum period will be detected by smallholder farmers, while 20-30 of those detected may be false (Mohamed, *et al.*, 1990). Thus the efficiency as well as accuracy of oestrous detection need to be improved by education and training. Since accurate detection of the time of onset of heat is more difficult in the buffalo than in cattle, this often results in mating or AI being done at the incorrect time.

Buffaloes subjected to free suckling by their calves resume ovarian activity much later after calving compared to those that are subjected to restricted suckling once or twice a day (Mohan, *et al.*, 1990; Abeygunawardena, *et al.*, 1996c). In cattle it has been shown that even the mere presence of the calf near its dam, and the degree of direct contact by touch, smell and sound, can delay the onset of postpartum ovarian activity in the dam (Williams, 1990).

The practical importance of the above is that farmers need the knowledge and skills to detect oestrus and mate cows at the optimum time, and to manage calves so as not to jeopardize the fertility of their dams.

Misconceptions

Rural dairy farmers in many Asian countries hold a range of misconceptions regarding the reproductive biology of cattle and buffaloes, which result in inappropriate management practices. Some farmers delay mating their cows for up to 3-6 months after calving, due to a belief that mating too early will result in a shortened lactation and lower milk production. Farmers also tend to assume that a cow will be pregnant once it has been served and neglect to look for returns to service, thereby losing valuable production time. On the other hand, many farmers believe that the discharge of blood which occurs 1-2 days after the oestrous period in a proportion of cows, termed met-oestrous bleeding, is a sign that the animal has not conceived after the preceding mating. Farmers in some communities also believe that buffaloes come into heat mainly around the time of the full-moon. Thus they neglect to detect heat at other times and, even more serious from the standpoint of fertility, submit cows which are not actually in heat for mating or AI on full moon days.

Dispelling such misconceptions is difficult and calls for innovative methods of education and extension, with clear messages that are compatible with the social and cultural background of these farming communities.

Reproductive Technologies

A range of modern reproductive technologies are currently available to livestock producers in developed countries. These are aimed at further improving the already high levels of productivity achieved using elite genotypes under specialized and intensive systems, and many of them are neither practical nor cost-effective under the traditional small-farm systems of Asia. However, as these systems become more intensive and commercially oriented, some of these technologies will

have good potential for application, particularly if due attention is paid to appropriate adaptation to suit specific local conditions.

Artificial insemination (AI)

Rapid genetic improvement requires the use of AI, particularly in the emerging intensive production systems of Asia, as it is often the only alternative, considering that keeping breeding bulls on small farms is expensive and impractical. The procedures for collection, evaluation, dilution, preservation and storage of buffalo semen are now well established (Vale, 1997). However, buffalo spermatozoa subjected to freezing and thawing appear to have a shorter fertile life span inside the female tract than fresh semen (Moioli, *et al.*, 1998). Thus proper detection of heat and timing of AI become critical when frozen semen is used and may be one reason for the differences seen in conception rates between AI and natural mating. Another factor that can contribute to poor conception rates is the narrow cervix of the buffalo, which makes AI more difficult, particularly in heifers.

The optimum time for AI in the buffalo appears to be towards the end of standing heat, which is later than that in cattle, when the cow refuses further mounting by teaser males (Moioli, *et al.*, 1998). In the majority of buffalo production systems, however, the use of teaser bulls is not practical. The option may be to inseminate cows around 24 hours after the first detection of heat signs, but this needs further research for confirmation.

Apart from these technical problems, there are many constraints that influence the quality and efficiency of AI services available in developing countries, as well as the effective utilization of these services by farmers. If genetic improvement and modernization of husbandry practices are to proceed, it is essential that the main constraints are clearly identified and appropriate steps taken to remedy them.

Measurement of progesterone in milk

Progesterone is produced by the Corpus Luteum (CL) in the ovary, and is present in blood, milk and other body fluids. One of the practical applications of progesterone measurement is its use for monitoring AI services and breeding management by farmers.

The rationale for this approach is illustrated in Figure 1. In a normally cycling buffalo cow, progesterone will be low at time of oestrus and increases from day 5 until day 10-14 (cows A and B). If the cow is mated at oestrus and it conceives, progesterone will remain elevated (cow A), whereas if the cow does not conceive, it will decline by day 16-18 and followed by an increase after the next ovulation (cow B). However, in some cases a cow may be inseminated because the farmer thought she was in heat; but progesterone levels will remain basal, indicating that she was acyclic or in anoestrous (cow C). There could also be occasions when a cow is erroneously inseminated during the luteal phase or during pregnancy.

In a recently completed co-ordinated research project involving 14 countries in Asia and Latin America (IAEA, 2000), three samples of milk were collected from each cow, on days 0, 10-12 and 20-23 after AI and assayed for progesterone. Information was recorded on the AI service, farming system, breeding management, nutrition and reproductive status of cows. The results, based on over 11,000 services in 7,990 cows on 1,735 farms, provided valuable insights to the level of fertility in cows bred by AI in these countries.

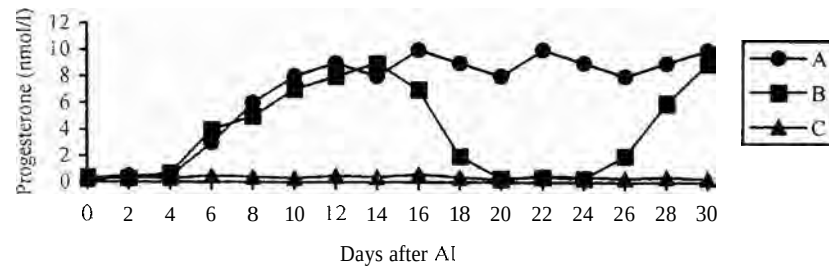


Fig. 1. Three profiles of progesterone concentration in milk of cows over a 30 day period after AI.

The conception rate to first service ranged from 15% to 52% in the study areas, with an overall mean of 41%. The main causes of low fertility were heat detection failure, insemination at the inappropriate time, poor semen quality, embryo mortality, seasonal influences and factors related to management on individual farms. Overall, 17% of cows were inseminated at an inappropriate time (range 2-55%). Of this, 7% (2-18%) were inseminated during the luteal phase or pregnancy and 10% (1-48%) were during anoestrus. Of the services performed at an appropriate time, 25% did not result in a pregnancy as diagnosed by progesterone measurement at 22-24 days (due to non-fertilization or early embryonic death). A high proportion of these cows were not submitted for further services until rectal palpation 2-3 months later, highlighting the failure of farmers to detect subsequent returns to oestrus. Of the animals diagnosed as possibly pregnant by progesterone assay, 12% were found to be non-pregnant on rectal palpation (due to late embryo mortality or persistence of luteal function). The efficiency of non-pregnancy diagnosis based on progesterone assay at 22-24 days after AI was greater than 95%. These findings highlight the need for closer monitoring of field results by AI service providers and for better education of AI technicians and farmers.

It is also possible to identify animals which have not conceived to AI by analyzing a single sample of milk collected between 20-23 days after AI (Perera, *et al.*, 1980), since basal progesterone levels at this stage are an almost infallible indicator of non-pregnancy. On the contrary, a high progesterone level only indicates that the animal may have conceived, since other conditions (*e.g.* AI during luteal phase, persistent CL, luteal cysts, late embryonic death) will also result in elevated progesterone at this time. For early positive diagnosis of pregnancy, measurement of pregnancy-specific protein B (PSPB) in blood can be done from 30-40 days onwards (Debenedettia, *et al.*, 1997).

An alternative to measuring progesterone could be the measurement of electrical resistance in the vaginal mucosa, which is known to be lower during oestrus than at other times of the cycle. A recent study showed that daily measurements from 19 days after AI, using a simple electronic probe, was capable of identifying a high proportion of cows that were non-pregnant and returning to heat (Scipioni and Foote, 1999).

There is clearly a potential in many dairy production systems of Asia to apply these methods as a diagnostic service to farmers. The advantage is that non-pregnant animals can be accurately identified at an early stage, and action taken to observe them closely for heat and to get them mated again at the correct time. The main disadvantages of the assay methods are the need for specialized laboratories and the logistics of getting the samples to the laboratory and the results back to the farm. If cheap and reliable qualitative cow-side tests for progesterone or PSPB are developed in the future, they will be valuable for improving reproductive efficiency under many smallholder buffalo production systems. The electronic probe, if proven to be reliable and available cheaply, could be a useful aid to veterinarians and AI technicians.

Oestrus synchronization

Synchronization of oestrus in a group of cows, or induction of oestrus prematurely in a single cow, can be used to circumvent the problem of heat detection and allows AI to be done on a pre-planned basis. The methods that have been used in buffaloes are based on those developed in cattle using progestational compounds with or without oestradiol, prostaglandins (PG), or combinations of these (Perera, 1987). Most studies have shown that the percentage of treated buffalo cows which come into heat is acceptable (70-90%), but the conception rate (CR) to AI performed at pre-determined times is around 20-40% (Pathiraja *et al.*, 1979; Rajamahendran *et al.*, 1980). Use of natural service, or AI after detection of heat by a vasectomized bull, can give CRs of 50-60%. One reason for this could be the finding that the interval from withdrawal of exogenous progestagens, or from treatment with PG to the occurrence of ovulation appears to be more variable in buffaloes than in cattle (Zicarelli *et al.*, 1997).

The success of synchronization programmes, particularly when undertaken in village farms under tropical conditions, depend on a number of factors including the biological peculiarities of this species, proper selection of animals for treatment, the synchronization regimes to be used, management aspects, semen quality, AI technique and climatic factors. Such programmes need to be properly planned and executed, if the obvious pitfalls evident in previously reported field programmes are to be avoided. The following recommendations should be considered in order to obtain acceptable fertility:

- Schedule synchronization during favourable periods of the year when the majority of animals are likely to be cycling
- Select females that are healthy and in good body condition
- Ensure animals are non-pregnant and cycling
- Avoid heat and other stresses during herding, treatment and AI
- Provide adequate water, feed and shade during all stages
- Use a treatment regime that is technically suitable for the specific conditions
- Ensure availability of good quality semen and skilled AI technicians
- Keep adequate records to enable evaluation of responses and results

Ultrasonography

Ultrasonography is now being used widely by veterinarians in the industrialized countries to visualize the reproductive tract of domestic animals, as a component of clinical diagnostic procedures. The main limitations to its application in developing countries at present are the capital cost of equipment and lack of experience among field veterinarians. However, there are indications that simpler, more portable and possibly cheaper instruments will be developed in the future. If so, this technique could become a valuable tool for veterinarians servicing smallholder farmers.

The most practical type of instrument is one based on real-time B-mode ultrasound, equipped with an intra-rectal transducer operating at 5 or 7.5 MHz. In buffaloes, the embryonic vesicle (non-echogenic) and the embryo proper (echogenic) can be imaged at about 19-27 days after mating. The heartbeat of the embryo is discernible at 30-35 days and structures such as the allantois, amnion, spinal cord and limbs can be imaged at 35-40 days. The stage of gestation can be deduced from the heart rate and the length of the embryo.

Embryo transfer and related technologies

The early experiences in buffaloes, with methods of embryo transfer developed for cattle were disappointing, but with recent advances in knowledge on buffalo reproductive physiology, the success rate is clearly improving (Drost, *et al.*, 1983; Jainudeen, 1990; Madan, *et al.*, 1996). Techniques have now been developed in buffaloes for ultrasound-guided ovum pick-up (Boni, *et*

al., 1996), *in vitro* fertilization and embryo culture (Madan, *et al.*, 1996) and embryo cloning from foetal fibroblasts (Parnpai, *et al.*, 1999).

In general, the superovulatory responses obtained, recovery of transferable embryos and pregnancy rates in buffaloes have been lower than those in cattle. This has been attributed to many factors, including differences in ovarian follicular populations, reproductive hormones, anatomical and biological aspects. The pregnancy rate in buffaloes is also influenced by factors such as synchrony between donors and recipients, embryo quality, size of CL in recipients and occurrence of premature luteolysis (Misra, *et al.*, 1999).

Given the current status, these technologies are likely to be applicable only under specific situations for improving buffalo production. Two such opportunities might be in providing the alternative of importing frozen embryos instead of live animals, when nucleus breeding stocks need to be established or in the conservation of rare genetic resources.

Sex pre-selection

In cattle, attempts have been made over the past several decades to pre-select the sex of offspring, principally by separating X and Y chromosome bearing spermatozoa. Of the many techniques that have been investigated, only the method based on high-speed flow cytometric cell sorting has provided reliable results (Seidel, 1999). This method at present can provide X-bearing sperms with a purity of 85-90% and a yield of 11 million sperms per hour (Johnson and Welch, 1999). Thus the yields are still too low for widespread application in routine AI, but sexed semen is currently being used in cattle for *in vitro* fertilization and low-dose deep uterine AI. Whether such methods will be applicable in buffalo breeding will depend on further refinements to the technology as well as improved delivery systems for breeding services.

Molecular methods of selection and related gene technologies

Traditional breeding methods for improving production are based on selection for desirable phenotypic characteristics. Technologies are now available for identifying and mapping the genes which control important traits, called quantitative trait loci (QTL). This provides a means of increasing the frequency of favourable alleles directly by selection of marker alleles known to be linked to the QTL allele (Gomez-Raya and Klemetsdal, 1999).

While the use of protein and DNA polymorphisms and microsatellite analysis methods are rapidly advancing, our knowledge on the genetic basis of many important traits, the practical applications of this knowledge for livestock breeding will need considerably more research and development. In the advanced production systems of developed countries, such technologies are aimed at pushing the limits of productivity further upwards in a cost-effective manner. In developing countries, however, they are more likely to find application in preserving the adaptive traits of indigenous livestock whilst increasing their genetic potential for production traits.

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HISTOLOGICAL CHANGES IN ENDOMETRIUM DURING FOLLICULAR AND LUTEAL PHASES IN WATER BUFFALO (*BUBALUS BUBALIS*)

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Abstract: While variations have been reported in the histological changes of uterus during follicular and luteal phases in mammals, the literature available on the cyclic changes of buffalo uterus is insufficient. This project was undertaken to study the normal histological structure of the buffalo uterus during the follicular and luteal phases in order to improve understanding of the changes during disease. As uterine disease affects fertility, the study of the empty or resting uterus appears to be more urgent than that of the pregnant uterus. The study concentrated on the endometrium because the disease often affected this part.

Sections of endometrium of 20 healthy water buffaloes (3-5 years old) during the follicular and luteal phases revealed an increase in the height and secretory activity of epithelial cells during the luteal phase. Cyclic erosion of the surface epithelium was seen in early dioestrus. The extravasation of blood, necrosis and epithelial desquamation, as well as oedema in the stroma of the endometrium were observed during the follicular phase. The branched tubular endometrial glands were not seen in the caruncular area. The number of the superficial glands was more during the luteal phase (69.8 ± 8.1 glands/mm²) than during the follicular phase (53.6 ± 7.8 glands/mm²). The diameter of the glands at the follicular phase (54.8 ± 6.9 μ) increased during the luteal phase (85.9 ± 8.6 μ). The results show that the endometrium of the buffalo uterus undergoes considerable structural changes during the luteal and follicular phases.

Keywords: Histology, endometrium, follicular phase, luteal phase, water buffalo

Introduction

While variation in histological changes of the uterus during follicular and luteal phases in mammals has been reported (Dellmann, 1987; Banks, 1996), the available literature on the cyclic changes of buffalo uterus is insufficient. This project was undertaken to study the normal histological structure of the buffalo uterus during follicular and luteal phases, in order to improve the understanding of the changes during disease. As uterine disease affects fertility, the study of the empty or resting uterus appears to be more urgent than that of the pregnant uterus. The study concentrated on the endometrium because the disease often affected this part.

Materials and Methods

Twenty normal uteri of 3-5 years old water buffaloes (*Bubalus bubalis*), during the follicular and luteal phases were collected at an abattoir. Samples were taken from left and right horns and fixed in 10% formal saline and processed by paraffin embedding and sectioned at 5-6 μ thickness. Tissue sections were stained with H & E special stains. Milligan trichrom, Fast green and PAS were employed where necessary for demonstrating special histological structures.

Results and Discussion

The cyclic changes chiefly affected the endometrium, which consists of a surface epithelium overlying a connective tissue stroma containing glands and blood vessels. The endometrial thickness increased during the luteal phase (Figs. 1 and 2). The cyclic changes of each component of endometrium are considered separately.

The surface epithelium

The pseudostratified columnar endometrial epithelium, which consists of ciliated and non-ciliated columnar cells, was situated on the thick basement membrane. Height and secretory activity of epithelial cells increased during the luteal phase. Vacuolization of these cells was considerable during the luteal phase. The pseudostratified surface epithelium of *Bubalus bubalis* endometrium has been reported also by Bhavsar *et al.* (1974). Harcharan-Singh and Sharma (1985a) reported heavy accumulation of lipid droplets in epithelial cells of buffalo endometrium during the mid-luteal phase, which gradually diminished from the late luteal to the follicular phases. The higher vacuolization of endometrial epithelial cells observed in this study during the luteal phase may be related to the aforementioned higher accumulation of lipid droplets during the late luteal phase. Bugalia and Sharma (1990) reported that glycogen and protein were significantly higher in buffalo endometrium during the follicular phase than the luteal phase.

The results also show that many of the cyclic changes of buffalo endometrial surface epithelium were comparable to those of cattle. Cyclic erosion of the surface epithelium was seen in the early dioestrus phase. The extravasation of blood, necrosis and epithelial desquamation were observed in the follicular phase (Fig.1). Dellmann (1987) reported that during proestrus, the bovine endometrium was again restored. The mucosa becomes thickened, congested and edematous with a predominance of mucin-filled epithelial cells. Metrorrhagia began shortly before the ovulation in the cow, Capillaries rupture in the mucosa and blood accumulated in cystic spaces beneath the surface epithelium. The blisters rupture and blood and shreds of mucosa were liberated into the uterine lumen. Weber *et al.* (1948) reported that the cyclic erosion of surface epithelium of the bovine endometrium occurred on the third day of the oestrous cycle. Arthur (1996) reported that 24-48 h after oestrous, the caruncles of the cattle uterus show petechial haemorrhages. Ohtani *et al.* (1993) reported that metrorrhagia and stromal oedema were greatest on day 0 - 1 and basal vacuolation of surface epithelium on days 5-6. The PAS reaction on apical parts of the epithelial cells of buffalo endometrium was seen both during luteal and follicular phases (Fig. 2). Oivadis *et al.* (1977) reported that during oestrus and metoestrus only non-ciliated epithelial cells of bovine endometrium have secretions.

The sub-epithelial connective tissue

Stratum compactum and stratum spongiosum were recognized just below the surface epithelium, but stratum spongiosum was more diffused during the follicular phase. However, these 2 layers were more differentiated at the luteal phase. Stroma consisted essentially of white fibrous tissue during the luteal phase (Fig. 2). Blood supply was poor during the luteal phase and the vessels were narrow with thick walls. Vascularization and congestion increased during the follicular phase. At the follicular phase, extravasation took place first below the surface epithelium and then through it into the lumen. Oedema was seen at the follicular phase and confined to the spongiosa. Dellmann (1987) reported that during oestrus, endometrial oedema and hyperaemia are maximal, and during metoestrus, the oedema lessens, but a breakdown occurred in some of the congested blood vessels of the mucosa.

The endometrial gland

The branched tubular endometrial glands were distributed throughout the buffalo uterus, but the glands were more concentrated on the basal layer of the endometrium. No glands were seen in the caruncular areas. Epithelium of the glands consisted of ciliated and non-ciliated columnar cells. The number of superficial glands was more during the luteal phase (69.8 ± 8.1 glands/mm²) than during follicular phase (53.6 ± 7.8 glands/mm²). The diameter of the glands at follicular phase ($54.8 \pm 6.9 \mu$) increased at the luteal phase ($85.9 \pm 8.6 \mu$). The cyclic changes in number and diameter of endometrial glands were significant ($P < 0.05$), (Table 1).

Table 1. The number and diameter of buffalo endometrium during follicular and luteal phases

Phase	Number of the superficial glands/mm ²	Diameter of the endometrial glands (μ)
Follicular	53.6 $\pm$ 7	54.8 $\pm$ 6.9
Luteal	69.8 $\pm$ 8.1	85.9 $\pm$ 8.6

Significance $P < 0.05$

There was an insignificant variation in the number and diameter of basal endometrial glands. Necrosis and epithelial desquamation of superficial glandular epithelium were observed at the follicular phase and glandular epithelium regeneration was seen at the luteal phase. Secretory activity and coiling of endometrial glands increased during the luteal phase. Janakiraman *et al.* (1976) reported that the highest number (47.75) of endometrial glands of water buffalo uterus per 100 X 100 cross section area were seen at the oestrous phase of the cycle, lowest (25.43) at the late luteal phase and intermediate (36.5) at the follicular phase. The gland epithelial cell wall height was lowest (106.5 μ) at oestrus and highest (146.13 μ) at the early luteal phase. The number of glands was lowest in the late luteal phase (46.3 glands/mm²) and increased from the early follicular phase (56.8 glands/mm²) to the mid-luteal phase (73.1 glands/mm²). The gland diameter was 61.3 and 99.9 μ at late and mid-luteal phases respectively. The authors had not seen glands in the caruncular areas and variation in number of basal glands, though not very significant, was greatest in the early follicular phase (221.8 glands/mm²). Uhrin (1984) reported that the proliferation of glandular epithelium is greatest in intensity in oestrus and reaches its peak values in metoestrus, when the apical parts of the cytoplasm contain the largest amount of smooth-walled vesicles and vacuoles, and also secretory granules.

Dellmann (1987) and Banks (1993) reported that the oestrogen (produced during the follicular phase) and progesterone (produced during luteal phase) are to a large extent responsible for the cyclic changes of the mammalian endometrium. Gordon (1996) has stated that the uterine degenerative changes are induced by oestradiol and continued by progesterone, which induced glandular secretory activity. The follicular and luteal changes observed in the buffalo endometrium structures may have been induced similarly.

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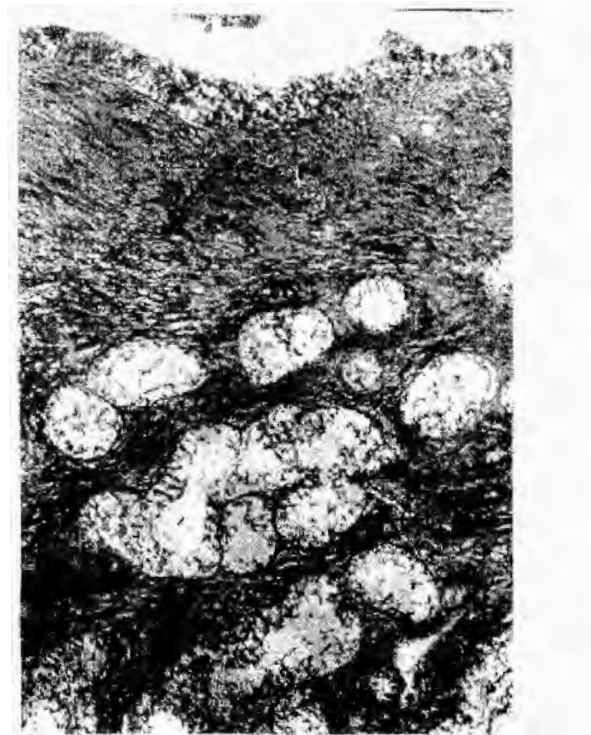


Fig.1 Photomicrography of buffalo endometrium during follicular phase. he de-epithelization with extravasation of blood cells; degenerated glandular epithelium (10X)



Fig. 2 Photomicrography of buffalo endometrium during luteal phase. The endometrial thickness and distribution of the glands are more than follicular phase (4X).

PERFORMANCE OF IMPORTED NILI RAVI BUFFALOES IN SRI LANKA IN RELATION TO ENVIRONMENTAL PARAMETERS

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Abstract: A study was conducted to assess the production and reproductive performance and to investigate the effects of environmental factors on performance parameters of imported Nili Ravi buffaloes in Sri Lanka. Data on calving, postpartum oestrus and lactation of 378 Nili Ravi buffalo cows, and birth weight (BWT), growth rate and age at first calving of 433 calves during the period 1991-1996 were analyzed in relation to ambient temperature (AT), relative humidity (RH) and rainfall (RF). The mean AT fluctuated between $22.7 \pm 0.5^{\circ}\text{C}$ and 32.211°C diurnally, while RH varied between 54.12% and 92.13%. The annual RF (1342 ± 99 mm) was bimodal, reaching the highest level from October to November, and a smaller peak from April to May. The majority (42.53%) of the calves were born from December to March, while $22 \pm 1\%$ calves were born in July and August. BWT of male (30.46 ± 3.11 kg) and female (28.57 ± 3.57 kg) calves were not different, but males became heavier (211.2 ± 25.3 kg vs. 187.2 ± 31.8 kg) than heifers at 12 mo of age. Of the environmental parameters, maximum AT ($r = -0.78$) of the month, nighttime RH of the previous month ($r = 0.80$) and RF of two months preceding the month of birth ($r = 0.64$) were significantly ($p < 0.05$) correlated to BWT implying the detrimental effects of heat stress and beneficial effects of RF on foetal nutrition during last months of pregnancy. Body weight gain (BWG) of calves declined from 3-6 mo of age suggesting weaning stress. BWG was lowest from 18-24 mo of age in heifers. Mean age at first calving was 1418 ± 255.2 days. The majority (65%) of heifers delivered first calf at 36 to 48 mo of age. Calving to first service (CFS) interval was 134.2 ± 93.2 d and varied ($p < 0.05$) depending on the month of calving and BWT of calves. CFS was shortest in cows that calved during November to January (41.5 ± 14.4 d) and longest in those that calved during February to April (185.9 ± 89.1 d). CFS was ($p > 0.05$) correlated to RH ($r = -0.65$), maximum AT ($r = 0.74$) of the month of calving, and to BWT ($r = -0.61$) suggesting that heat stress lowered BWT and increased CFS, while RF during prepartum dampened such effects. Percentage conception was correlated ($r = 0.74$; $p < 0.05$) to the RF of previous 5 months indicating beneficial effects exerted by RF on conception. Gestation length ($321.175.9$ days) was not different between the two sexes. Calving interval (465.0 ± 148.5 days), lactation milk yield (1732.5 ± 639.8 kg) and lactation length (291.4 ± 75.2 days) declined with parity. Daily milk yield increased till third month of lactation to reach a peak yield of 7.73 ± 1.5 kg/day and declined thereafter. These results suggest that the peri-partum period as the most vulnerable stage to environmental stress, and maximum AT, nighttime RH and RF as the most important environmental factors affecting the performance. Alleviating heat stress during prepartum is suggested as a means for improving reproduction performance of cows and BWT of calves. Need for improving existing weaning practices to avoid weaning stress, plane of nutrition of heifers at 18-24 mo of age to improve growth performance and advance age at puberty and improving nutrition of lactating cows to prevent the decline in lactation performance with parity also are indicated by the results.

Keywords: Postpartum, birth weight, milk yield, environment, Nili Ravi buffalo

Introduction

As in many other countries in Asia, the water buffalo plays a considerable role in the livestock sector of Sri Lanka contributing approximately 25% of national milk production and providing draught power to about 35% of the total cultivated land extent. Since the production performance of the indigenous buffalo, which constitutes the majority of the 0.8 million buffalo population in Sri Lanka, is far from satisfactory, numerous attempts have been made in the recent past to improve their potential. Importation of exotic river breeds of buffaloes from countries such as India and Pakistan, to be used as nucleus herds in upgrading and cross breeding programmes of indigenous buffalo, had been one of those endeavours. Under the animal importation programme, three breeds of buffaloes namely, Murrah, Surti and Nili Ravi had been imported to Sri Lanka from time to time. Nili Ravi buffaloes imported from Pakistan were maintained at a state owned livestock farm located in the dry zone of Sri Lanka, as a nucleus herd from the time of importation. The production performance of imported Murrah buffaloes in Sri Lanka had been

investigated (Rajamahendran *et al.*, 1980-81; Lundstrom *et al.*, 1982), and comparisons had been made with those of Nili Ravi buffaloes during their first two years of performance (Abeygunawardena *et al.*, 1995). However, information is lacking on the production and reproduction performance of imported Nili Ravi buffaloes and their descendents in relation to changes in the environmental factors in Sri Lanka. Hence, this study was undertaken to examine the production and reproduction performance of imported Nili Ravi buffaloes in Sri Lanka and the relationship of these parameters to the environmental variables, with the ultimate goal of identifying the aspects that warrant immediate attention to enhance the production and reproduction performance of these imported animals and their descendents.

Materials and Methods

The data used in this study were collected from the National Livestock Development Board (NLDB) farm located at Nikaweratiya, where the 271 imported Nili Ravi buffaloes, and a limited number of their descendents are maintained as a nucleus herd. The Nikaweratiya NLDB farm is located in the Kurunegala district of the North Western Province of Sri Lanka at latitude, longitude and an elevation of 7° 44' N, 80° 08' E, and 100 ft, respectively.

The general management practice adopted by the farm during 1990-1996 period was a combination of zero grazing and semi-intensive management as described in the following section. The imported animals commenced calving in 1991. During the first two to three months postpartum, the buffalo cows were managed under zero grazing, given a mixture of *Bracharia brizantha*, *Bracharia mutica* and available native grass *ad libitum*, and fed up to 5 kg/day of a concentrate mixture containing 95.1% dry matter, 13.7% crude protein and 74.2% total digestible nutrients, at milking time. Water showers were provided to cool these cows during the hottest part of the day, and they were hand milked twice a day at 0300 and 1500 hours. Beyond 3 months postpartum, the buffalo cows were sent for grazing in the field from 0630 hours till 1330 or 1400 hours and allowed to wallow from 1330 hours till 1500 hours before being hand milked at 1500 hours. Three to five stud bulls were used daily to detect the cows in oestrus. Although the females were served naturally, artificial insemination services were sometimes used. The calves were separated from the dam at 5 days of age, and raised in calf boxes for two months. The calves were completely weaned from milk by three months of age, and fed on grass and concentrate mixture at the rate of 0.5 kg/day. Bull calves were separated from the females and the best were selected as future breeding stock, while the rest were sold from 7 to 9 months of age onwards. The heifers and dry cows were primarily raised on roughage under grazing management with minimal concentrate feeding (–2.5 kg/day/animal).

Data on dates of calving, birth weight and sex of the calves born in the farm, interval from calving to first service in postpartum cows, daily milk yield and length of lactation of lactating cows and monthly body weight of calves until 12 months of age were obtained periodically from the available records. Data concerned with abortions, stillbirths, nymphomania and lactations less than 100 days were excluded from the analysis because, such incidences were considered to be abnormal. Similarly, records of sick animals, and records after 1996, when the management of the animals was changed drastically from the above description, were also not considered, so as to eliminate the effects of management and health conditions. After excluding all the above-mentioned 'abnormalities', only the data from 378 cows and 433 calves were included in the analysis.

Meteorological data on daily ambient temperature (AT), relative humidity (RH) and rainfall (RF) from 1991 till 1996 were obtained from the Kurunegala meteorological station and the farm. The mean weekly and monthly AT, RH and RF were estimated from this data and used for the analysis. The statistical mean values of the above mentioned production and reproduction traits were estimated. These values were correlated with the weekly and monthly means of maximum AT, minimum AT, daytime RH, nighttime RH, and RF of the same week and month. Data on birth weight was correlated to AT, RH and RF of one and two months before birth. Correlation

coefficients were computed between the monthly calving percentages and AT, RH and RF prevailed during 10 to 17 months before calving to estimate the relationship between conception rate and environmental parameters. Whenever, a significant correlation was revealed, the respective linear regression coefficients were computed. Data on lactation milk yield, lactation length, and body weight were subjected to analysis of variance to examine the affects of time and parity.

Results

Meteorological data

The mean monthly ambient temperature, relative humidity, and rainfall that prevailed in the area during the study period are given in Table 1. Ambient temperature fluctuated diurnally between 20.2°C and 35.2°C. Relative humidity varied between 54% and 77% during daytime and 79% and 92% during nighttime, assuming an opposite directional fluctuation to that of AT fluctuations. Mean monthly AT was highest in March and lowest in December. Nighttime humidity had significant positive correlations (Table 2) with daytime humidity ($r=0.79$; $p<0.01$) and rainfall ($r=0.73$; $p<0.01$). The annual precipitation of the area (1392 ± 99 mm) varied depending on the month of the year ($p<0.05$), reaching minimal values in February and maximal values in November. Annual RF showed a distinct bimodal pattern, yielding a major amount of precipitation (67% of annual RF) during October to December and a minor peak in March to May (20% of annual RF). February was the driest month, March the hottest, while November was the wettest and most humid month of every year.

Table 1. Mean monthly ambient temperature, relative humidity and rainfall (1991-1996)

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Minimum	Maximum	Night	Day	
January	20.2	31.0	80.0	64.0	49.9
February	20.5	34.0	75.5	51.5	6.0
March	22.5	35.3	82.5	55.5	65.6
April	23.6	34.2	85.0	64.5	88.6
May	24.3	32.5	87.0	71.1	130.9
June	24.2	30.2	84.5	74.5	20.2
July	23.7	30.4	84.1	74.0	54.9
August	24.0	31.2	82.0	69.0	9.7
September	23.7	32.6	79.5	65.5	57.1
October	22.8	31.5	88.0	70.5	405.4
November	22.1	30.7	89.0	74.0	411.9
December	21.5	30.0	85.0	69.0	115.5

Calving pattern

Monthly distribution of the number of calves born as a percentage of the total number of calves born during the year is given in Table 3. These values indicate that while calving occurred throughout the year, two peak seasons of calving do exist. The highest percentage of births ($47\pm3\%$ of total) took place between December to March, primarily in February and March ($33\pm2\%$ of total), while another smaller peak period of calving ($22\pm1\%$ of total births) was evident during July and August. In each of the remaining months, approximately 3-6% of total number of calf births took place monthly. Correlation analysis of the monthly percentage of births with the monthly AT, RH, and RF that prevailed during 10 to 17 months before birth revealed that the monthly percentage of births had the highest positive correlation to monthly RF that prevailed 16 months before birth ($r=0.74$; $p<0.05$). This regression equation representing this significant linear relationship was $\% \text{ calving} = 5.439 + 0.0246 \text{ RF}$ ($R^2 = 0.55$, $p<0.05$).

Table 2. Correlation coefficients among the calving-to first service interval (CFS) birth weight (BW), rainfall (RF), minimum temperature (MIT), maximum temperature (MAT), daytime humidity (DH) and night humidity (NH)

	NH	DH	MAT	MIT	RF	BW
CFS	-0.47	-0.64'	0.74**	0.12	-0.36	-0.61*
BW	0.66*	0.44	0.05	0.45	0.63*	
RF	0.73**	0.42	-0.21	-0.07		
MIT	0.50*	0.56*	0.01			
MAT	-0.36	-0.75**				
DH	0.79**					

* P < 0.05, ** P < 0.01.

Table 3. Monthly distribution of calving percentages and birth weights of calves

Month	Percentage Calving	Birth weight (kg)
January	7.1	30.4 ± 3.5
February	15.7	28.4 ± 4.8
March	16.4	28.2 ± 3.3
April	3.6	28.4 ± 5.4
May	3.6	29.6 ± 3.0
June	5.0	29.7 ± 4.4
July	9.3	30.5 ± 5.8
August	13.6	30.9 ± 5.3
September	6.4	29.2 ± 4.7
October	5.7	27.9 ± 5.0
November	3.6	30.0 ± 3.0
December	10.0	32.0 ± 3.1

Birth weight (BWT)

The overall means birth weight of the calves born during 1991-1996 was 29.6±4.63 kg. The birth weight of male calves (30.5±4.52 kg) was not significantly different from that of female calves (28.6±4.58 kg). However, birth weight was affected ($p<0.05$) by the month of birth. The heaviest calves (32±3.1 kg) were born during December, while those with lowest mean birth weights (27.9±5.0 kg) were born in October (Table 3). Correlation and regression analysis of birth weight with AT, RH and RF indicated that birth weight was negatively correlated to maximum ambient temperature of the month ($r=-0.78$, $p<0.01$) of birth, positively related to night humidity ($r=0.80$, $p<0.01$) of the previous month, and rainfall during the previous month ($r=0.57$, $p<0.05$) and calving ($r=0.54$; $p<0.05$). The respective regression equations depicting the significant relationships between birth weight and maximum AT (MAT) of the month of birth, rainfall two months before birth (RF2) and night humidity of the previous month (NH1) are given in Figure 1a, b, and c.

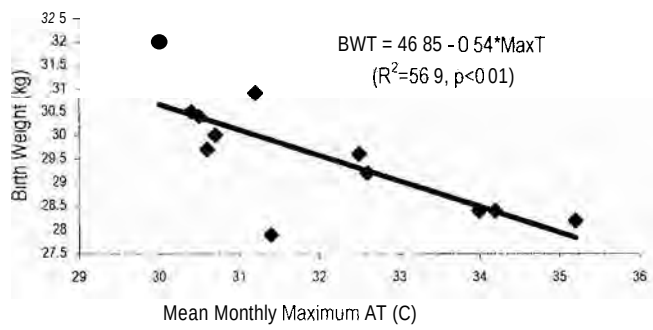


Fig. 1a Relationship between birth weight and mean monthly maximum ambient temperature

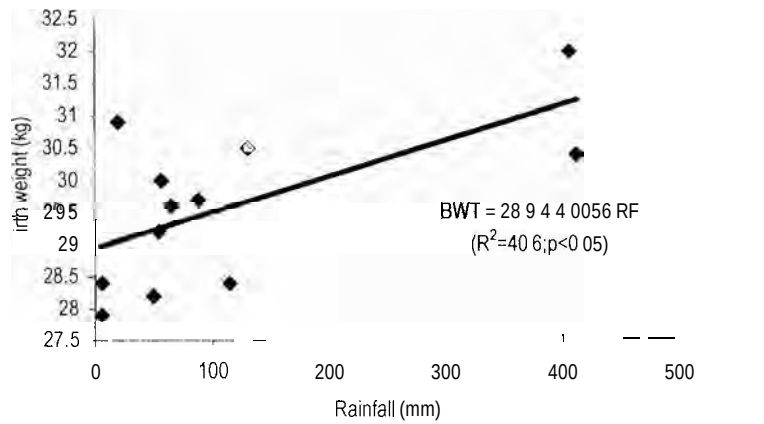


Fig. 1b Relationship between birth weight and monthly rainfall two months before birth

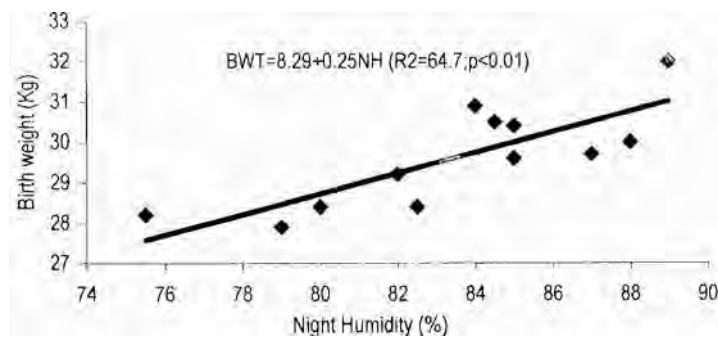


Fig. 1c Relationship between birth weight and night humidity

Body weight gain

Mean daily body weight gain of the male and female calves from birth till twelfth month of age is given in Table 4. In both sexes, the daily body weight gain increased up to the third month, declined from third till the sixth month and again increased from the sixth to the twelfth month of age. This growth pattern resulted in male and female calves reaching a live weight of 211.2 ± 25.3 kg and 187.2 ± 31.1 kg, respectively at 12 months of age. When body weight gain of calves that had a lower birth weight (25.51 ± 2.55 kg) than the overall mean birth weight (29.59 kg) was compared with that of calves that had a higher than the overall mean birth weight (33.29 ± 2.60), the heavy calves had superior body weight gains (Table 4; $p < 0.05$). Due to insufficient number of data points on body weight of male calves beyond 12 months of age, only the body weight gain of heifers older than 12 months of age was considered. These values indicated that, the weight gain of heifers was lower ($p < 0.05$) during 18 to 24 months of age compared to the other stages of growth.

Table 4. Age related changes in body weight gain (kg/day) of Nili Ravi buffalo

A& (Months)	Heavy (>29.59 kg)	Light (49.59 kg)	Male	Female
0 – 1	0.226	0.197	0.191	0.197
1 – 2	0.432	0.369	0.421	0.401
2 – 3	0.499	0.468	0.463	0.462
3 – 4	0.326	0.313	0.380	0.361
4 – 5	0.368	0.351	0.307	0.322
5 – 6	0.264	0.240	0.359	0.330
6 – 7	0.762	0.298	0.472	0.451
7 – 8	0.605	0.520	0.502	0.531
8 – 9	0.544	0.335	0.431	0.462
9 – 10	0.599	0.569	0.730	0.593
10–11	0.538	0.591	0.562	0.611
11 – 12	0.662	0.548	1.191	0.692
12 – 18				0.411
18 – 24				0.267
24 – 30				0.475

Age at first calving

The mean age at first calving ranged from 1077 to 2415 days and assumed a mean value of 1418 ± 255.2 days. This was approximately 46.5 ± 8.4 months, which ranged from 35.3 months to 79 months of age. Less than 1% of the heifers delivered the first calf before 36 months of age, while the majority (84%) of heifers calved for the first time between 36 and 60 months of age. A smaller number (15%) delivered the first calf beyond the age of 60 months. Of the heifers, that calved for the first time between 36 and 60 months of age, approximately 65% (55% of total heifers) calved between 36 and 48 months of age.

Calving to first service (CFS) interval

The above parameter, when estimated as the interval from calving to first detected oestrus or first service, ranged from 12 days to 453 days with a mean value of 134.2 ± 93.2 days. Calving to first service interval was affected by the month of calving (Table 5). Mean length of calving to first service period was lowest (41.5 ± 14.4 days) in cows that calved during the November to January period, while it was longest in cows that calved during February, March (185.9 ± 189.1 days) and August (153.9 ± 101.2 days). In about 40% of all the cows that calved during the study period, the calving to first service interval was < 50 days, while another 30% had the first service after calving within 61 to 180 days postpartum. In the remaining 30%, the length of calving to first service was > 180 days (Figure 2). Of the cows that were served less than 60 days postpartum,

40% consisted of all the cows that calved during November, December and January when the ambient temperature was low.

Correlation and regression analysis of calving to first service period with AT, RH and RF revealed that the calving to first service period was significantly correlated to maximum ambient temperature ($r=0.74$, $p<0.05$), humidity ($r=-0.65$, $p<0.05$) and RF ($r=-0.36$; $p>0.05$) in the month of calving. Calving to first service interval was longest in cows that calved in February and March, when the ambient temperature was highest and RF was lowest. Similarly for cows that calved in August, when the AT was modest but RF was lower, the calving to first service interval was considerably high. An interesting negative correlation existed between birth weight of calves and calving to first service period ($r=-0.61$, $p<0.05$). The regression equations depicting the above significant linear relationships are given in Figures 3a, b and c.

Table 5. Month of calving and respective calving to first service (CFS) interval

Month of calving	CFS (Days)	Mean of 3 months
February	194.2	
March	203.2	185.9 ^b
April	111.4	
May	90.4	
June	101.4	100.6 ^c
July	106.1	
August	153.9	
September	117.3	134.3 ^c
October	120.5	
November	44.0	
December	40.6	41.5 ^a
January	39.5	

^{a, b, c, d} values in a column that differ at $p<0.05$

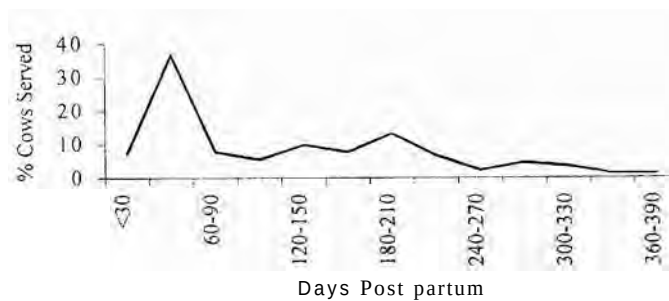


Fig. 2. Percent cows served versus days postpartum

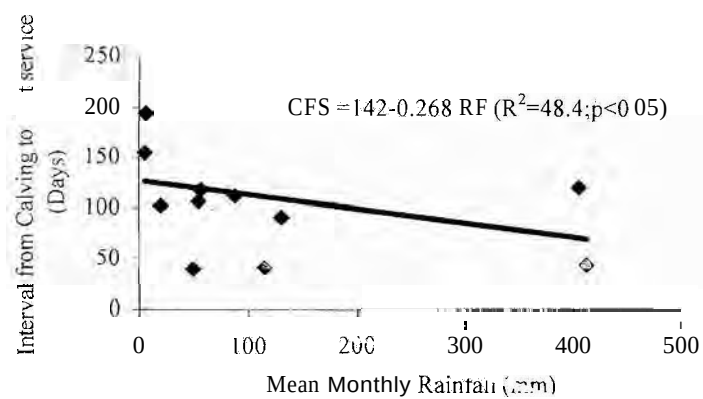


Fig. 3a. Relationship between rainfall and calving to first service (CFS)

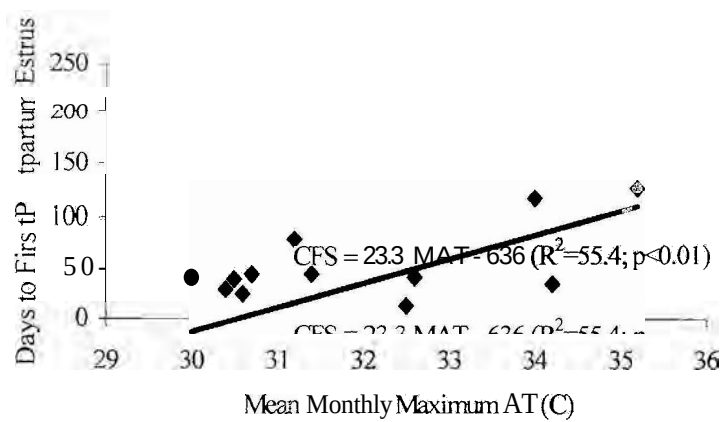


Fig. 3b. Relationship between mean monthly maximum AT (MAT) and calving to first service (CFS)

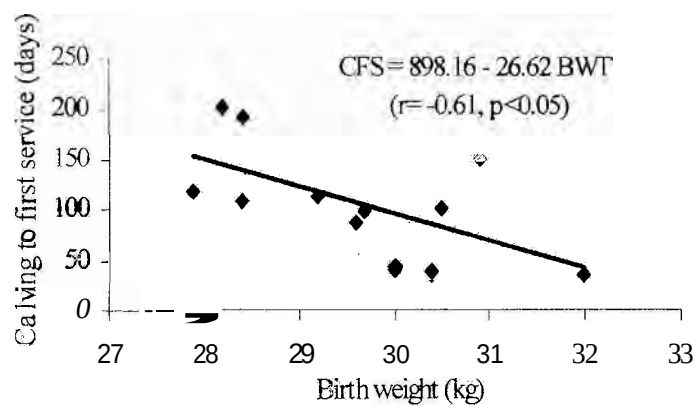


Fig. 3c. Relationship between birth weight and calving to first service

First service conception rate

According to the available records on dates of service of cows, the first service conception rate was 54%. No significant relationship could be derived from the correlation analysis between the first service conception rate and environmental parameters.

Gestation length

Gestation length as estimated from the period from last service to subsequent calving was 328 ± 75.9 days. No significant difference in gestation length attributed to the sex of the calf could be detected.

Calving interval

The overall calving interval was 465.2 ± 149.0 days. This parameter declined ($p < 0.05$) from the first calving to the fourth calving. The calving intervals of cows following the first, second, third and fourth calvings were 529.1 ± 152.5 days, 431 ± 136.3 days, 428 ± 121.0 days and 354 ± 20.5 days, respectively. About 10.8% of all the cows had calving interval of more than 365 days, while another 10% of cows experienced calving intervals of more than 570 days. The majority (59.3%) of the cows had a calving interval of between 420-510 days. No significant relationship could be detected either between calving interval and calving to first service interval, or between calving interval and environmental parameters during the month of calving.

Calving to conception interval

The length of the calving to conception interval as estimated by the difference between estimated calving interval and gestation length was found to be 137 ± 37.5 days, which was not different ($p > 0.05$) from the calving to first service interval (134 ± 21.3 days), suggesting a very high first service conception rate. However, when estimated as the difference between estimated calving interval and standard gestation length of the buffalo (310 ± 5 days), the interval from calving to conception amounted to 155.5 ± 56.5 days suggesting a lower first service conception rate.

Lactation

Lactation length varied between 195 to 330 days, giving a total milk yield of 1044.5 to 1883.6 kg. Daily milk yield varied between 4.88 and 7.39 kg during different stages of lactation to achieve an overall mean value of 6.0 kg/day. Highest daily milk yield (7.73 kg) was recorded in the third month of the second lactation.

Lactation milk yield and lactation length declined with parity. Mean lactation milk yield and lactation length of the first, second, third and fourth lactations were 1870.1 ± 6581.7 kg in 326.0 ± 89.7 days, 1697.1 ± 638.0 kg in 276 ± 73.3 days, 1685 ± 645.1 kg in 272 ± 62.4 days and 1078 ± 610.9 kg in 202 ± 144.8 days, respectively (Figure 4).

Discussion

The bimodal pattern of RF, high AT and RH during the study period represents the typical climatic conditions prevailing in the dry zone of Sri Lanka. Birth weight of calves was greater than the average birth weights recorded for Murrah, Surti and indigenous buffaloes under Sri Lankan condition. Birth weight of an animal is determined by breed as well as environmental factors which affect maternal nutrition and thereby the growth rate of the foetus. The effect of the environment on foetal growth via maternal nutrition is most pronounced during the last trimester of pregnancy, when the foetal growth is at its maximum. Heat stress impairs maternal as well as foetal nutrition. The negative relationship of birth weight with mean of the maximum daily AT of the month of birth suggests the detrimental effects of high environmental temperature conditions

on foetal nutrition during prepartum. The negative relationship exhibited between birth weight of calves and subsequent calving to first service interval suggests that adverse environmental conditions not only lower the birth weight of calves, but also increase the calving to first service interval.

The positive correlations of RF of the previous month and that of two months before birth with the birth weight suggest enhancement of the foetal growth rate during last two months of pregnancy when these two months coincided with the rainy months. Rainfall affects the nutrition of all the animals (pregnant and non-pregnant) as the primary and major component of their feed comprised of naturally available forage, of which the quantity and quality depend on RF. In addition, KF alleviates heat load on animals as evidenced by the negative relationship between maximum AT and RF of the month. All these beneficial effects of RF are reflected by the positive correlations detected between RF during the two months preceding calving and birth weight of calves

Results on superior body weight gain experienced by calves that were heavier at birth compared to those that were lighter at birth, agrees with the norm. The reduction of body weight gain from 3 to 6 months of age in both sexes suggest weaning stress, and implicate the necessity for improvement of nutritional management at weaning and adopting proper weaning procedures for calves. The significantly superior body weight gain in male animals from 9 months of age till 12 months of age could be attributed to the better feeding management practices adopted for these animals after being selected for future stud purposes. The decline in body weight gain in heifers from 18 to 24 months of age suggests sub-optimal nourishment and management received by these heifers, which do not contribute to any economic benefit in terms of farm income or milk yield.

The majority of the heifers included in this study (88%), calved for the first time between 36 and 60 months of age, while the majority of this group (65%) delivered the first calf between 36 and 48 months of age, resulting a mean age at first calving of 46.5 ± 8.4 months. Age at first calving is a function of the age at puberty, which in turn is reached at an age when the heifer reaches a threshold body weight. Growth rate depends on birth weight and plane of nutrition. Based on the results, improvement of plane of nutrition for heifers in the age group of 18 to 24 months is suggested as a means of advancing age at puberty and thereby the age at first calving to enhance reproductive performance of these animals.

Calving to first service interval was affected by AT, RH and RF. The relationships implicate calving to first service interval as being subjected to thermal stress and the alleviation of thermal stress through reduction of heat load by RF. Hence alleviating thermal stress during postpartum would shorten the interval from calving to first oestrus. However, the lack of a relationship between calving to first service interval with calving interval and the poor first service conception rate, suggests that heat stress alleviation alone will not bring the desired improvements in reproductive performance and that it should be accompanied by improvements in other factors, such as timing of insemination and plane of nutrition, which affect the first service conception rate. Reduction of calving to first service interval with parity suggests that the time taken for resumption of postpartum ovarian activity declines as the animals mature. Resumption of postpartum ovarian activity depends on reactivation of hypothalamic pituitary ovarian axis. Reactivation of the axis depends on both metabolic and environmental cues. The delay in resumption of postpartum ovarian activity in first calf heifers suggests greater importance of internal metabolic cues for these growing animals during this period. Since the metabolic cues and hormonal balance primarily depend on nutrition, these results implicate the importance of providing an improved plane of nutrition for these first calf heifers, which are still growing.

The observed decline in lactation performance with parity in these cows was contrary to the expectations. Lactation milk yield is a function of secretory tissue amount and efficiency of milk biosynthesis. Amount of secretory tissue in the mammary gland increases with age and lactation

up to the third lactation, while the efficiency of milk biosynthesis primarily depends on available nutrients. The observed decline in lactation performance with parity suggests a decline in nutrition and/or management of these animals after the first lactation.

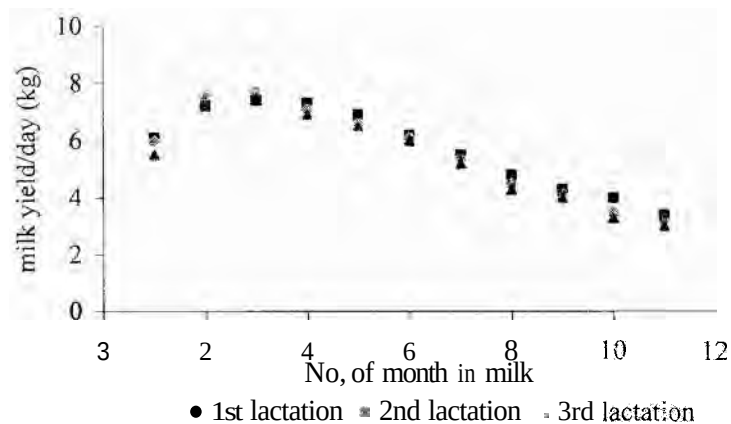


Fig. 4. Mean daily milk yield of Nilli Ravi buffalo in different lactations

Conclusion

The results of this study indicate that, among the production and reproduction parameters that were investigated, birth weight of calves, calving to first service interval and percentage conception are more sensitive to the changes in ambient environmental conditions, especially of maximum AT, night-time RH and RF, suggesting the peri-partum period to be the most vulnerable stage, to the direct and indirect effects of adverse environmental conditions. Adverse thermal ambient conditions during pre-partum reduce birth weight of calves and extend calving to first service interval in cows. Alleviating thermal stress during this critical period reverses these effects. Existing weaning practices of calves should be improved to avoid weaning stress, and nutrition of 18-24 month old heifers need to be improved to enhance growth and reproduction performance. Improvement of the plane of nutrition of first calf heifers warrants attention to reduce their calving to first service interval. Immediate attention should be paid to improve the nutrition and management of lactating cows, to minimize the decline in lactation performance with advancing parity.

Acknowledgements

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Performance of Nili Ravi buffaloes

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SYMPOSIUM - III

Reproduction

Discussion

Q. A. Borghese - Yow is it that your conception rates are low, because 3 days after the removal of the implant heat signs can be seen and you get high conception rates.

A. B.M.A. Oswin Perera - The conditions are very difficult under our situations. For example, when you collect a group of buffaloes, they are already stressed. They have to be treated. They are not used to being handled by strange people who have come to do this procedure. They have never been inseminated before. If you try to inseminate a buffalo that is not used to AI, you will find they are very distressed. So that all adds up this. It is not the technology, but how you handle it under these conditions.

Comment: M.R. Jainudeen - With regard to identification of animals that are presented for PRID, generally in our countries, when the farmer brings the animal for the second time, he may not remember which animal he brought the first time. So you may get a different animal at times.

A. B.M.A. Oswin Perera - Sometimes we try to use a method that has been developed under very uniform conditions, but in the field under a different set of conditions one may not get the desired results. It is important to remember that sometimes animals are herded and kept without even feed and water for 5-6 hours in the sun. If you check their rectal temperature, you will find that they are stressed.

Q. M.R. Jainudeen - You were talking about difficulties in oestrus detection. There are now a new technology, sperm encapsulation which has been developed in New Zealand. They can keep the sperm in a capsule that will release the sperm slowly. So, we don't have to be very accurate.

Q. R.S. Navaratnam - There is a lot of importance given to oestrus synchronisation on a large scale. I don't know that situation in other countries, but if you go on doing this on a large scale, will not be selecting animals that are poor manifestors of heat? We will then be unwittingly or deliberately selecting such animals. Can I have your comments please?

A. B.M.A. Oswin Perera - If it has to do with cattle, it is possible that this can happen, under the hand mating system, where the farmer does the detecting of heat. Then you may go and pick up the animals where the farmers could not detect heat. It may be an animal that by nature shows little manifestations of heat. That is possible. But, if it is under the extensive system, the bull will detect heat without a problem. So, if it is a natural mating system, you will be selecting animals that are cycling after the bull is removed. Under those situations, the difficulty is that you will be selective non-cycling animals, because they are the ones that are non-pregnant. You may find that there is something in the ovary that looks like a corpus luteum, which you think is a corpus luteum. But the animal is really non-cycling. This is why very often animal that are non cycling are inseminated. With buffaloes, if it is a hand mating system, generally buffaloes show less signs of heat and one must first think carefully what the objectives are. If it is to breed as many animals as possible, yes this can be done, but it may cause other problems.

Q. P. Skunmun - You said that the buffalo is a seasonal breeder.

A. B.M.A. Oswin Perera - I was referring to those countries where there is seasonality of breeding occurs. I didn't mean that buffaloes are seasonal breeders, like sheep due to the photoperiod, nutrition and climate. In such situations, oestrus synchronisation should be done in the season when the buffaloes are breeding and not when animals are not in season.

Q. S.C. Kaduwela - In NLDB Farms, we use this intra-vaginal device on buffalo heifers. We selected 10 animals of which 9 conceived, but with cows only 14 out of 28 cows conceived on the first occasion.

A. B.M.A. Oswin Perera - The number is difficult to give as a percentage. Most likely, your heifers were cycling well and in good condition.

Comment: O.P. Dhanda - Our experience is that there is not much difference. This depends on the efficiency of the technician. We do 100% AI on buffaloes and the conception rate is 56%, which is comparable to cattle. Secondly, you made an observation regarding mating oestrus breeding buffaloes. May be the percentage is very low because in the case of cows, and cross-brads the metoestrus breeding is very high, I have not come across any buffaloes where this phenomenon is present. What are your observations?

A. B.M.A. Oswin Perera - In studies carried out in Italy, it was shown that the optimum time for AI in buffaloes was later than that in the cow. With regard to metoestrus breeding, I can't quote any published results, but we do see it.

VIRAL INFECTIONS OF BUFFALOES – ROTAVIRUSES AND HERPESVIRUSES

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Abstract: The medical and veterinary consequences of viral infection of man and animals have altered our history and have resulted in extraordinary efforts on the part of virologists to study, understand and eradicate these agents. Virtually all living organisms when studied carefully have viral parasites. Buffaloes are no exception.

In spite of the importance of the buffalo as a farm animal in Asia, there is a paucity of information concerning their viral infections. Only a few viral infections of buffaloes have been described in the literature; foot and mouth disease, buffalo pox, rabies and infectious bovine rhinotracheitis amongst them. One of the major drawbacks in increasing the buffalo population in Sri Lanka is the high calf mortality rate, which is mainly attributed to respiratory and enteric diseases. Rotaviruses are the major viral pathogens causing diarrhoeas in infants, children of 6 months to 2 years of age, and in calves, lambs and piglets. In Sri Lanka too, rotavirus infection amongst buffalo calves and their association with diarrhoea have been established in 1988.

Buffaloes like many other ruminants are hosts for members of the herpesvirus family. A wide range of disease syndromes is associated with infections with these agents. Unlike many other viruses, herpesviruses are not eradicated from the host following primary infection. They can establish latency in neuronal cells or in lymphoid cells. Various stimuli can provoke reactivation of latency leading to the re-establishment of lytic virus replication. In addition to the rotavirus infection of buffaloes, the pathogenic potential of an alpha herpesvirus; bovine herpesvirus type-1 (BHV-1), and a gamma herpesvirus; malignant catarrhal fever (MCF) virus in relation to the features of homologous human herpesvirus infections will be discussed

Key words: Buffalo viruses, rotaviruses, herpesviruses

Introduction

Viruses have been associated with infections of man and animals for millions of years and they continue to cause disease outbreaks leading to mortality and morbidity. Small pox, the scourge of mankind during the middle ages was eventually controlled in the 19th century by the 'new' process of vaccination, which is now the principal method for controlling many infectious diseases.

Although many viral diseases such as rabies, poliomyelitis were known to mankind for thousands of years, the identification of a virus as a disease agent in animals was first established in 1898, with the discovery of the foot and mouth disease (FMD) virus. In 1901, yellow fever virus was discovered as the first human virus (Levine 1995). Since then, many viruses causing human and animal diseases have been discovered and mechanisms for controlling such infections have been devised due to the extraordinary efforts on the part of virologists to study, and eventually eradicate these agents. Although most of these viruses only infect either man or only one species of animal hosts there are several viruses that infect both man and animals frequently causing the clinical disease in humans. These zoonotic infections are now frequently observed with new additions to existing infections in the form of emerging or re-emerging infections. This has arisen as a result of loss of animal or vector habitats due to urbanisation, deforestation and other man made changes to the environment. Hantaviruses responsible for adult respiratory distress syndrome in the USA, Japanese encephalitis virus, Nipah virus (a paramyxovirus) encephalitis in Malaysia and bat lyssavirus rabies in Australia are examples of recent or resurgent zoonotic viral

diseases. Therefore, understanding the natural cycle of animal viruses, whether they are from birds, pigs, rodents or from buffaloes provides an important foundation for the global surveillance of emergent infections.

In spite of the importance of the buffalo as a farm animal in Asia, there is a paucity of information concerning their viral infections. Only a few viral infections of the buffalo have been described in the literature e.g. FMD, buffalo pox, rabies and infectious bovine rhinotracheitis amongst them (Sunil-Chandra, 1988; Siriwardene, *et al.*, 1999). Two of the major drawbacks in increasing the buffalo population in Sri Lanka is high calf mortality and reproductive disorders (de Silva, *et al.*, 1985). Studies in Sri Lanka and in India have shown that buffalo calf mortality is an important problem and enteritis is one of the major conditions contributing to high mortality and calf wastage (Rai, *et al.*, 1982; Srivastava and Sharma, 1983; Bhullar and Tiwana, 1985; de Silva, *et al.*, 1985 and Subasinghe, 1986). This review aims to highlight the nature of rotavirus and herpesvirus infections of buffaloes in relation to transmission, pathogenesis and immune responses.

Buffalo Rotaviruses

Rotaviruses are the major viral pathogens causing diarrhoea in infants, children of 6 months to 2 years of age and in calves, lambs and piglets. Amongst the viral aetiologies of diarrhoeas, the group A or typical rotaviruses are considered the most important (Bridger 1980; Butler, 1984). These viruses have a genome of 11 segments of double stranded RNA, which can be readily separated by polyacrylamide gel electrophoresis. The wheel-like appearance of the double shelled virus particles seen by electron microscopy is diagnostic (Desselberger, 1998). Classification of rotaviruses is based on the antigenic characteristic of the virus and its genomic composition. Groups A-E can be differentiated according to the antigenic specificities of the inner capsid protein VP6 with polyclonal and monoclonal antibodies. Within the group A rotaviruses, subgroups I, II, I+II, non I and non II are classified according to exclusive reactivities of two VP 6 monoclonal antibodies (Greenberg, *et al.*, 1983). The serotyping and genotyping of rotaviruses within the group A is determined by cross neutralisation and by sequence comparison respectively (Desselberger, 1998). Recently, a double classification system has been established for rotaviruses that differentiate G types (glycoprotein VP7 genotype of the virus) and P types (protease sensitive virus protein genotype of the virus). It is known that all G types can be differentiated into serotypes but not all P types. At present there are 14 G types and around 19 P types identified, indicating an extensive genomic diversity amongst the group A rotaviruses (Estes, 1996).

In an effort to investigate the aetiology of buffalo calf diarrhoea in Sri Lanka in 1988, diarrhoeic faecal samples of buffalo calves located in different areas of the island were screened by antigen capture ELISA for the presence of rotavirus antigens (Sunil-Chandra and Mahalingam, 1994a, 1994b, 1995). This study clearly established for the first time the association of rotavirus with buffalo calf diarrhoeas in Sri Lanka. The association of rotaviruses with diarrhoeas in buffalo calves has also been reported in India and Bulgaria. (Singh, *et al.*, 1985; Mittal, *et al.*, 1986 and Muniappa, *et al.*, 1987).

Buffalo rotaviruses detected from clinical specimens belonged to the group A rotaviruses, as determined by the antigen capture ELISA using group A specific hyperimmune antisera raised on rabbits and guinea pigs (Beards, 1984; Sunil-Chandra, 1988; Sunil-Chandra and Mahalingam, 1994). In order to determine the subgroup specificity of these buffalo rotavirus strains, all positive clinical specimens and tissue culture isolates (in MA 104 cells) from antigen positive buffalo diarrhoeic specimens were tested by the antigen capture ELISA using monoclonal antibodies (mouse Mabs AF255 & AF631) specific for subgroup I and II antigens (Sunil-Chandra and Mahalingam, 1996). However, further characterisation of the buffalo rotaviruses into G and P types is yet to be carried out in order to understand their epidemiology in Sri Lanka, in relation to the rotaviruses circulating amongst humans and other domestic animals.

Transmission and pathogenesis of rotaviruses

Rotaviruses are transmitted via the faecal oral route and infect small intestine following oral ingestion. Multiplication of the virus occurs in the mature epithelial cells at the tips of the villi of the small intestine. Cell death and desquamation of the infected villi cells results in reduced digestion, malabsorption of nutrients and villous atrophy. This is followed by reactive crypt cell hyperplasia accompanied by increased secretion, which contributes to the severity of diarrhoea (Desselberger, 1998). After a period of 1-2 days incubation, rotavirus infection in infants and children, leads to a sudden onset of illness characterised with watery diarrhoea, vomiting and dehydration.

A study on an outbreak of rotavirus infection in a herd of buffalo calves in Sri Lanka (Sunil-Chandra and Mahalingam, 1995), revealed that the pattern of infection and the disease is similar to that described in humans and other farm animals, with the exception that vomiting was not a feature of the illness observed in buffalo calves. Furthermore, the severity of clinical signs of infected buffalo calves varied from mild to severe diarrhoea. In this outbreak, conditions such as overcrowding and prolonged housing of calves were found to be the factors increasing the chance of faecal contamination within the calf pen which may have led to the spread of disease (Sunil-Chandra and Mahalingam, 1995).

Immune response to rotaviruses

After primary infection, a serotype specific humoral immune response is elicited leading to partial protection against subsequent heterotypic infections. The exact degree of protection is not well determined but antibodies of IgA subclass present in the colostrum and milk appear to be the most important. The exact role of rotavirus specific cell mediated immune responses is not known (Desselberger, 1998).

Studies under natural farm conditions in Sri Lanka, on the acquisition and decline of maternal anti-rotaviral antibodies in buffalo calves via colostrum, showed that most of the calves had anti-rotaviral antibodies of maternal origin. However, the protective role of these antibodies in that particular study was not determined (Sunil-Chandra and Mahalingam, 1995).

Herpesviruses

Herpesviruses are linear double stranded DNA viruses of eukaryotes comprising more than 80 distinct viruses isolated from a wide variety of animal species including man, and are responsible for a variety of important diseases (Roizman, 1985). Buffaloes like many other ruminants are host members of the herpesvirus family. A wide range of disease syndromes is associated with infection with these agents. On the basis of distinctive biological properties such as features of virus replication, cytopathology and characteristics of acute and latent infections, the family of herpesviruses are classified into three broad groups namely; alpha herpesviruses, beta herpesviruses and gamma herpesviruses (Minson, 1989; Roizman, *et al.*, 1995). Known ruminant herpesviruses belong to either alpha- or gamma- herpesviruses (Sunil-Chandra, 1991). Unlike many other virus families herpesviruses are not eradicated from the host following the primary infection. They can establish latency in neuronal cells or lymphoid cells. Various stimuli can provoke reactivation from latency leading to the re-establishment of lytic virus replication.

Alpha herpesviruses

Alphaherpesviruses typically cause mild primary infections of epithelial cells of skin, eyes, oral cavity, respiratory and genital tracts of the primary host species characterised by productive virus replication leading to the lysis of infected cells. They are also capable of causing severe infections in their natural host species and can produce generalised fatal infections among neonates or immunocompromised adults. Following primary infection alpha herpesviruses persist in a latent

form, which may give rise to periodic recurrence. The sites of the latency appear to be neurons of the sensory ganglia innervating the site of the primary infection (Wildy, *et al.* 1982; Honess, 1984). The human counterparts of the alpha herpesviruses include herpes simplex virus (HSV -1 & -2), responsible for gingivostomatitis, cold sores and genital herpes, and varicella zoster virus (VZV) which causes chicken pox and shingles.

Gamma herpesviruses

Gamma herpesviruses are represented by the causative agent of infectious mononucleosis; Epstein-Barr virus in humans which is associated with Burkitt's lymphoma and nasopharyngeal carcinoma. These viruses are generally termed lymphotropic viruses and have the capacity to establish latency in lymphocytes. They can produce a lymphoproliferative disease in the infected host and can efficiently immortalise lymphocytes infected *in vitro*. On the basis of available data and for convenience, gamma herpesviruses are subdivided into lymphocryptovirus (gamma-1) and rhadinovirus (gamma-2) families (Honess, 1984).

Diseases associated with buffalo herpesviruses

Infectious bovine rhinotracheitis (IBR) / infectious pustular vulvovaginitis (IPV)

Infectious Bovine rhinotracheitis caused by bovine herpesvirus-1 (BHV-1) is a worldwide acute, contagious disease of bovines characterised by fever, general depression, drop in milk production and emaciation. Nasal and tracheal turbinates are primarily involved and bronchopneumonia may result from secondary bacterial infection. Abortion of infected pregnant females, meningoencephalitis in young calves, conjunctivitis and mastitis may be observed in infected animals. Another syndrome caused by a BHV-1 virus is infectious pustular vulvovaginitis (IPV) and balanoprophitis in bulls. Infection with IPV strain of BHV-1 leads to pustular lesions of the genital tract of males and females. As with the homologous human herpes viruses, BHV-1 also produces a latent infection in neuronal cells whereby the latent virus can be reactivated. Cattle are the principal reservoirs of BHV-1 but serologic studies in other ruminants representing families; Bovidae, Cervidae and Giraffidae and Suidae have been reported.

In Australia, alpha herpesviruses from buffaloes have been differentiated from BHV-1 on viral DNA restriction profiles, indicating alphaherpesvirus of buffaloes may be a distinct species (Engels and Ackermann, 1996). Although much of the knowledge on alpha herpesvirus infections come from the studies on human viruses, there are many questions relating to buffalo herpesvirus infections that need to be addressed, including their isolation, characterisation, and pathogenesis.

Although respiratory diseases and reproductive disorders are major factors contributing to the decrease of buffalo population in Sri Lanka, there have been no studies carried out to elucidate the prevalence and the pathogenic potential of BHV-1 or other types of herpesviruses of buffaloes.

Transmission and pathogenesis of BHV-1

BHV-1 infections are easily transmitted by aerosol or by close contact from one animal to other due to large quantities of virus shed in respiratory, ocular and reproductive secretions of infected animals. Shedding by latently infected animals does not seem to be as abundant or long lasting as during acute stage. BHV-1 can also be transmitted by contaminated semen during artificial insemination of cows or milking machine cups. After primary infection the virus multiplies at the portal of entry in the mucosa of the respiratory and genital tracts. The virus is then transported by monocytes and probably by other white blood cells via the blood stream to the target organs such as central nervous system, digestive tract, the foetus, or the udder. Another route of virus spread occurs through peripheral nerves similar to the pattern of HSV and VZV infections of man.

Entry of the virus to the peripheral nervous system occurs following the replication at the local site of infection leading to the establishment of virus latency in the neurones of the trigeminal and sacral ganglia. Virus is then maintained in the latent state by the host immune system. Reactivation of the latent virus may occur either spontaneously or induced by natural or artificial stimuli such as transport, parturition and immunosuppressive treatments, such as dexamethasone.

Malignant catarrhal fever (MCF) in the water buffalo (*Bubalus bubalis*)

Malignant catarrhal fever is a dramatic, fatal disease affecting many species of bovidae including buffaloes characterised by a wide spread lymphoproliferation and degenerative changes affecting most tissues (Reid and Buxton, 1989). There are several different gamma herpesviruses that can induce MCF but only one designated alcelaphine herpesvirus-1 (AHV-1) has been characterised to any extent (Reid and Buxton, 1989). AHV-1 causes an inapparent infection of its natural host, the wildebeest (*Connochaetes taurinus*), but the transmission of virus from these carrier animals to susceptible ruminants results in development of MCF which leads to severe economic losses in Africa and in Zoological gardens.

In addition to the wildebeest associated MCF in Africa, a sheep associated form (SA-MCF) identified as ovine herpesvirus-2 (OHV-2) causes a worldwide problem of MCF in cattle, buffaloes and other susceptible ruminants. Furthermore, seroepidemiological studies implicate goats as possible carriers of SA-MCF (Bridgen, 1991; Sunil-Chandra, 1991).

SA-MCF is of major economic concern in Indonesia where susceptible animals such as Balinese cattle (*Bos javanicus*) and water buffalo (*Bubalus bubalis*), the main source of draught power and income to small farmers, are commonly housed together with sheep and goats. It is becoming clear that domestic buffalo and Bali cattle are very much more susceptible to SA form of MCF and therefore, the MCF has become a serious animal disease problem in this region.

Transmission and pathogenesis of MCF

The disease occurs in two different circumstances following direct or indirect contact either with wildebeest or with sheep. Both forms of this virus appear to be transmitted at high frequency during wildebeest calving or during lambing season (Fenner, *et al.*, 1987). MCF due to infection from wildebeest is not restricted to areas in Africa, but also occurs in zoological parks worldwide where these species are kept. Transmission from wildebeest to susceptible ruminants occur following close contact, but reports from zoological parks indicate the occurrence of aerosol spread.

In contrast to the wildebeest associated form, the SA form is distributed worldwide and probably occurs where cattle and sheep are reared. The disease normally occurs sporadically affecting only few animals at a time although the incidence of infected cattle and buffaloes is now more common (Reid and Buxton, 1989). As with MCF induced by AHV-1, intimate contact between sheep and target species is not always required for the SA agent transmission. For example a recent study into the death of 50 water buffaloes was suspected to be SA-MCF, but the flock of lambing sheep was over 30 metres away. This strongly suggests that the virus is efficiently transmitted *via* aerosol.

The pathogenesis of MCF appears to be due to the result from virus-induced proliferation and dysfunction of T lymphocytes (Reid and Buxton, 1984). Lymphoblastoid cell lines have been propagated from animals affected with MCF and some of them can transmit MCF to susceptible animals (Wiyono, *et al.*, 1994). Although it appears that B lymphocytes are the site of the latent SA-MCF agent (OHV-2), in the natural host, there is a controversy on the identification of sites virus latency in susceptible animals (Wiyono, *et al.*, 1984; Baxter, 1997). The two main components of the pathology of MCF are T lymphocytes proliferation and tissue necrosis.

including terminal destruction of lymphoid tissues, epithelial surfaces, blood vessels and other tissues (Reed and Buxton, 1989).

Immune response to herpesviruses

The primary infection stimulates a strong humoral and cell mediated immune response. In the case of BHV-1, although the neutralising antibodies are able to eliminate free virus, the cell-mediated immune responses appeared to be important for the recovery from the disease (Engels and Ackermann, 1996). Despite the strong immune response during initial infection, the infected animals are unable to eliminate the virus. BHV-1 evades the effectors of the immune system as they migrate back to the peripheral tissues along the nerve tracts. The effectiveness of the humoral immune system is thus reduced.

In the case of MCF, humoral antibody responses can be detected but directed at only a few of the viral epitopes. Cattle infected with AHV-1 develop non-neutralising and neutralising antibodies detected occasionally during the final stage of the disease. The significance of these antibodies is not clear. In contrast, cell mediated immune responses are suggested to be involved in protective immunity and in the pathogenesis of lymphoproliferative disease (Reid and Buxton, 1989; Engels and Ackermann, 1996).

Diseases of buffaloes due to virus infection remain largely unexplained. In view of the economic importance of this animal more detailed investigations are required for key diseases caused by viruses. Molecular tools used widely in diagnosing and studying human herpesvirus infections should now be common place in laboratories studying buffalo diseases. It is only through a concentrated effort by the research community and funding agencies that progress on preventing these diseases of buffaloes will be possible.

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PREVALENCE OF *CRYPTOSPORIDIUM* INFECTION IN BUFFALO CALVES IN THE NORTHWESTERN PROVINCE OF SRI LANKA

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Abstract: This study was undertaken to determine the prevalence of *Cryptosporidium* infection in the Northwestern Province of Sri Lanka where diarrhoea is recognized as an important clinical entity in buffalo calves. A further objective was to ascertain whether the buffalo could be a reservoir of human cryptosporidiosis reported in children in the province.

Faecal samples were collected from 110 buffalo calves (either sex, below 6 months of age, mixed breeds) managed in three institutional farms (Nikaweratiya, 37; Melsiripura, 53; Narangalla, 20). *Cryptosporidium* oocysts were isolated from faeces using the Sheather's sucrose floatation technique followed by identification of the parasite using the modified Ziehl Neelsen (MZN) technique. The identity of parasitic oocysts was further confirmed by additional staining techniques that included Giemsa, nigrosin and the modified trichrome.

The overall prevalence of the infection was 10 per cent (11/110) however, the prevalence of the infection varied between farms. The Melsiripura farm had a prevalence of 19% (10/53) while in Nikaweratiya it was 2.7%. *Cryptosporidium* oocysts were not detected in animals from Narangalla. Of the 11 buffalo calves positive for the infection only one animal was diarrhoeic, the others were asymptomatic. The findings of this study indicate a relatively high prevalence of *Cryptosporidium* infection in buffaloes and that this species should also be included as a potential animal reservoir for human cryptosporidiosis. Asymptomatic animals excreting oocysts of *Cryptosporidia* have been reported from other ruminants. They may have an impact on the epidemiology of the disease in both man and animals.

Key words: *Cryptosporidium* infection, buffalo, zoonotic disease

Introduction

Diarrhoea caused by infectious agents is recognized as one of the most important causes of morbidity and mortality in buffaloes, particularly in calves (Cockrill, 1974). Common aetiological agents responsible for infectious diarrhoea in buffaloes include parasites such as *Toxocara vitulorum* and *Eimeria* spp, bacteria, especially *Salmonella* spp and *E. coli* and viruses that include rota and corona viruses (Adlakha and Sharma, 1992). The protozoan parasite, *Cryptosporidium* has now come to be recognized as an important enteropathogen responsible for diarrhoea in a wide variety of farm animals as well as in immunocompetent and immunocompromised humans (Current and Garcia, 1991).

Most reports relating to cryptosporidiosis in farm animals are based on studies in cattle. The first description of cryptosporidiosis in cattle was made in the early 1970s where it was found to be associated with chronic diarrhoea and debilitation in an eight-month old calf (Panciera *et al.* 1971). Following this report, several workers have incriminated *Cryptosporidium* to be associated with neonatal calf diarrhoea and many of these occurrences have been mixed infections with enteropathogenic bacteria and viruses (Snodgrass *et al.* 1980). However, Tzipori *et al.* (1980) showed *Cryptosporidium* to be the only demonstrable cause of enteritis in a natural outbreak of calf diarrhoea. Further the role of *Cryptosporidium* as a primary pathogen in diarrhoea was clearly shown in a series of experiments conducted by Tzipori *et al.* (1981) and Anderson (1984).

Although cryptosporidiosis in buffaloes was reported much later when compared to cattle, it is now recognized as an important enteropathogen responsible for diarrhoea and weight loss in this species (El-rahim, 1997; Galiero, 1999). Transmission of *Cryptosporidium* within and between host species is primarily through the faeco-oral route following ingestion of fully sporulated, environmentally resistant oocysts excreted from clinically affected or asymptomatic carriers (Scott *et al.*, 1995). Infected farm animals are known to excrete millions of oocysts in the faeces and to act as reservoirs of human infection (Smith and Rose, 1998).

In Sri Lanka, cryptosporidia has been identified in the faeces of calves (Bahirathan *et al.*, 1987), diarrhoeic children (Perera, 1988; Perera and Lucas, 1990; Mertens *et al.*, 1990) and more recently, in goats (Noordeen *et al.*, 2000). A survey on the causes of diarrhoea in children showed *Cryptosporidium* to be the most common parasite present in faeces of diarrhoeic children (Perera *et al.* 1999). The present study was designed to determine the prevalence of *Cryptosporidium* in buffalo calves in the Northwestern province which has the highest buffalo population in the country and where cases of human cryptosporidiosis has been reported in children.

Material and Methods

One hundred and ten faecal samples collected from buffalo calves (mixed breed; below 6 months of age) managed in three institutional farms (Nikerweratiya, 37; Melsiripura, 53; Narangalla, 20) were examined. The faecal samples were collected directly from the rectum, placed in separate polythene bags and brought to the laboratory in a polystyrene box maintained at 4°C.

The faecal samples were concentrated using a sucrose floatation technique in order to provide quantitative estimates of oocyst numbers. Briefly, 2 g of faeces was emulsified with 25 ml of distilled water and sieved through a strainer into a 50-ml centrifuge tube. Sheather's sucrose solution (sucrose 2268g, phenol crystals 29.5g, distilled water 1452ml) was added to the latter tube to make it up to a volume of 50-ml and then centrifuged for 10 min at 400g. The top meniscus (5 ml) was carefully aspirated and added to a second 50 ml tube containing distilled water and centrifuged for a further 10 min at 400g. The supernatant was discarded and the pellet was washed twice by resuspending it in 50-ml distilled water followed by centrifugation for 10 min at 400g. After second centrifugation, the supernatant was aspirated leaving 2 ml of the suspension at the bottom of the tube. A 10 µl aliquot of the suspension was spotted on a glass slide for the preparation of a thin smear. Air-dried, methanol fixed smears were stained using the modified Ziehl Neelsen (MZN) technique (Casemore, 1991).

The total number of oocysts in the smear was counted under a microscope (x 1000). The number of oocysts per gram of faeces was calculated by modification of the method described by Scott *et al.*, (1995) for cattle, in that 2 g of faeces was used instead of 5 g. In addition to the MZN technique, *Cryptosporidium* was demonstrated by the Giemsa, nigrosine and modified trichrome staining procedures.

Results

The overall prevalence of the infection was 10% (11/110) however, the individual prevalence of the infection varied between farms (Table 1). The Melsiripura farm had a prevalence of 19% (10/53) while in Nikaweratiya it was 2.7%. *Cryptosporidium* oocysts were not detected in animals from Narangalla. Of the 11 buffalo calves positive for the infection only one animal was diarrhoeic while the others were asymptomatic.

Table 1. Prevalence of *Cryptosporidium* in buffaloes in the three institutional farms

Farms	Number of animals examined	Number positive	Prevalence (%)
Melsiripura	53	10	19
Nikaweratiya	37	1	2.7
Narangalla	20	0	0
Overall	110	11	10

Discussion

In Sri Lanka, *Cryptosporidium* infection has been reported among humans, cattle calves and goats, but this is the first report of the infection in buffaloes. The results of the present study indicate that *Cryptosporidium* is a relatively common parasite among buffaloes in some of the institutional farms in the NorthWestern Province.

Bathirathan *et al.* (1987) in a preliminary study on the prevalence of *Cryptosporidium* in calves showed that 2 of the 26 animals examined in an institutional farm in the mid country were infected. Conversely, a more extensive study in goats conducted by Noordeen *et al.* (2000) has shown that the prevalence varied from 32.6% in the dry zone to 21.4% in the wet zone, and that the overall prevalence of the infection in three zones, which included the intermediate zone was 28.5%. In the present study, the overall prevalence of the infection in buffaloes is 10% and reflects the findings of only three institutional farms. Work is in progress to extend this survey to include other farms, especially the small holder buffalo farms where a majority of the animals in the province are managed.

Studies in Italy have shown that the between farm prevalence of *Cryptosporidium* varies from 23% and 38% (Galiero, 1999). Given the fact that transmission of the infection is through faecal-oral contamination, a high prevalence could be expected when animals are managed under an intensive system where the likelihood for the spread is high. In the present study, the between farm variation was marked, in that in one farm none of the animals were infected while in the other, the prevalence was 19%.

Infectious neonatal buffalo calf diarrhoea resulting in growth retardation, morbidity and mortality are identified as major constraints to buffalo production worldwide (Adlakha and Sharma, 1992). Investigations on the cause of diarrhoea in buffaloes have identified a variety of infectious agents, which include parasites, bacteria and viruses, and it is recognized that diarrhoea is a complex disease process often involving multiple aetiological agents. The protozoan parasite, *Cryptosporidium* has been identified as an important enteropathogen both in man and animals. Results of the present study showed that one of the 11 animals with diarrhoea showed *Cryptosporidium*. However, the evidence presented herein is insufficient to conclude whether *Cryptosporidium* is a primary pathogen, as other causes of diarrhoea were not examined.

Of the 11 buffalo calves which were found to be infected with *Cryptosporidium* only one had diarrhoea while the others were found to be asymptomatic. Studies in goats (Noordeen *et al.*, 2000) as well as in cattle (Scott *et al.*, 1995) have shown that a large proportion of the infected animals are asymptomatic, while excreting oocyst in their faeces, and that these asymptomatic carriers could have a major impact on the epidemiology of the disease both in humans and buffalo calves.

Human cryptosporidiosis is caused by *Cryptosporidium parvum* (Current and Garcia, 1991) while cryptosporidiosis in animals could result from *Cryptosporidium parvum* or *Cryptosporidium muris* (Graff *et al.* 1999). Immunofluorescence methods using monoclonal antibodies and species-specific primers in PCR are used in the speciation of cryptosporidia. These techniques are being pursued to identify the isolates recovered from buffaloes in this study.

Studies in humans have indicated that cryptosporidiosis is one of the protozoan zoonosis in Sri Lanka and cattle calves are thought to be the animal reservoir of the infection (Dissanaike, 1993). Recent studies have indicated that goats are a potential source of human infection (Noordeen *et al.*, 2000). The findings reported herein indicate that the buffalo could also be an important source of human cryptosporidiosis and the close interaction between humans and buffaloes, especially in rice farming and associated activities provide an opportunity for possible transmission of the infection from animal to man.

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CLINICAL AND PATHOLOGICAL CHANGES IN BUFFALOES FOLLOWING INTRAVENOUS INOCULATION OF ENDOTOXIN EXTRACTED FROM *PASTEURELLA MULTOCIDA* TYPE 6:B

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Abstract: Recent experimental studies on haemorrhagic septicaemia in buffaloes using *P. multocida* serotype 6:B have incriminated endotoxin (LPS) to be responsible for the acute clinical course and death of infected animals. This observation had been pursued in the present study by evaluating the dose response to intravenous LPS extracted from the organism.

Eleven Lanka buffalo calves (3-6 month of age; 45-72 kg body weight) of either sex were used in the experiment. The animals were divided into three groups, Group 1 and 2 having with four animals each and Group 3 with three animals. Animals in Group 1 and 2 received intravenous lipopolysaccharide (LPS) in 10 ml of PBS at a dose rate of 3 and 5 µg/kg body weight, respectively. Group 3 animals received the same volume of PBS only by the intravenous route and served as controls. Clinical examinations were performed, and jugular blood were collected for haematology 1 hr prior to and at the time of inoculation and also at 1, 3, 6, 12, 24, 36, 48, 72, 96 and 120 hr post inoculation (pi). The LPS used in this experiment was extracted from a field isolate of the organism using the aqueous-phenol extraction method.

The demeanour of LPS inoculated animals when expressed as dullness scores ranging from 0 to 3 depending on the degree of severity. It was noted that the highest scores were present 1 to 3 hours, pi. The salient clinical signs in these buffalo calves included anorexia, dyspnoea, profuse salivation, pyrexia, lowering of the head and sternal recumbency. The haematology was characterized by marked leucopenia between 3 and 6 hr, pi. One animal each from Group 1 and 2, died 36 and 24 hr pi, respectively. In both animals, postmortem examination revealed very similar changes which included severe lung oedema and congestion, diffuse haemorrhage with multifocal erosion of the abomasal mucosa and extensive subendocardial and subepicardial haemorrhages. The clinical, haematological and pathological changes following intravenous *P. multocida* LPS reported herein closely resemble the findings in naturally occurring and experimentally induced haemorrhagic septicaemia in the buffalo, suggesting a role for LPS in the pathogenesis of the disease.

Keywords: Buffalo, endotoxin, *Pasteurella multocida*

Introduction

Haemorrhagic septicaemia (HS) in buffaloes which is caused by the Gram negative bacterium *Pasteurella multocida* is essentially characterized by two clinical syndromes (De Alwis, 1995). One is the manifestation of the disease with an acute fibrinous bronchopneumonia that may have a clinical course extending a few days, but the most common presentation of HS is sudden death preceded by a very short clinical course. Experimental infection following intranasal inoculation of the organism has successfully reproduced both forms of the disease but the virulence factors leading to the sudden onset of the disease and rapid death are poorly understood. Recent experimental studies (Horadagoda *et al.*, 2000), using the whole organism, demonstrated a marked endotoxaemia a few hours prior to death, indicating the possible role of phosphate buffered saline lipopolysaccharide (LPS) in the pathogenesis of the disease. Indeed many Gram negative bacterial infections are known to mediate tissue injury and death through virulence expressed by endotoxin, a component of the outer cell wall of these bacteria. In this study, the role

of LPS in the pathogenesis of HS has been pursued by investigating the clinical and pathological changes in relation to the dose response to intravenous LPS, extracted from the organism.

Materials and Methods

Eleven 3-6 month old Lanka buffalo calves of either sex, weighing between 45 to 72 kg were used in this study. The animals were selected following screening for the absence of *Pasturella multocida* in the nasopharynx as well as the absence of serum antibodies to the organism by the indirect haemagglutination test. The calves were divided into three groups, Groups 1 and 2 with 4 animals each and Group 3 with three animals. Animals in Groups 1 and 2 received intravenous LPS, in 10 ml of PBS at a dose rate of 3 and 5 µg/kg body weight, respectively. Group 3 animals received intravenous PBS only, and served as controls. The endotoxin used in this experiment was extracted from a field isolate of *P. multocida* serotype 6:B (VRI strain 8402) using the aqueous-phenol extraction method described by Wesphal *et al.* (1952). Clinical examinations were performed and jugular blood was collected for haematology 1 h prior to and at the time of inoculation, and also at 1, 3, 6, 12, 24, 36, 48, 72, 96 and 120 h, post inoculation (pi).

The clinical examination at each time point included the assessment of respiration and heart rates, rectal temperature and observations of demeanour. The haematological analysis included the enumeration of erythrocytes and leucocytes using an improved Neubauer haemocytometer, assay of haemoglobin by the cyanmethaemoglobin method and determination of the packed cell volume using a microhaematocrit centrifuge (Jain, 1986). Post-mortem examinations were conducted on animals that died during the experiment and tissue samples were collected for histopathological examination.

Results

The demeanour of animals is expressed as a dullness score ranging from 0 to 3 depending on the degree of severity (Table 1). On this scale, the highest scores were noted 1 to 3 hours after LPS inoculation. The salient post inoculation clinical findings observed included anorexia, dyspnoea, salivation, pyrexia, lowering of head and sternal recumbency. Animals in both inoculated groups showed a transient pyrexia between 3 and 12 hours, post-inoculation (Fig. 1). One of the animals (No. 1600) that died about 20 h after inoculation showed a pyrexia followed by a rapid decline in the temperature to reach sub normal levels. Dyspnoea was present but it was not a consistent feature in all the animals. In the haematological analysis, the most characteristic change was associated with the leucocyte counts, which showed a marked leucopenia between 3, and 6 hours, pi (Figure 2). There were no significant changes in the erythrocyte indices, such as the red blood cell counts, haemoglobin concentration or the packed cell volume. One animal each from the Groups that received 3 and 5 µg/kg of LPS, died after 36 hours, and 24 hrs, respectively. Postmortem examination revealed severe lung congestion and oedema (Figs. 3 and 4) and histological sections of the abomasal mucosa show congested blood vessels and haemorrhages (Fig. 5).

Discussion

The considerable overlap in the clinical, haematological and necropsy changes between acute experimental HS (Horadagoda, *et al.*, 1991) in buffaloes and the responses to these two doses of *P. multocida* used in the present study suggest that LPS may indeed be a virulence factor in initiating rapid onset and consequent death in HS. Different animal species and individuals within the same species are known to have variable sensitivities to LPS. These responses may also vary with the bacterial species from which LPS was extracted. In the present study, some of the buffaloes succumbed to doses of 3 and 5 µg/kg of *P. multocida* LPS, but cattle calves were able to tolerate up to 25 µg/kg of *E. coli* LPS administered intravenously (Tikoff, *et al.*, 1966).

Table 1. Individual dullness scores in animals inoculated with intravenous endotoxin. Animals in Group 1 and 2 received 3 µg/kg and 5 µg/kg, respectively. The controls were given 10 ml PBS only.

	Time (h)												
Animal No.	-1	0	1	3	6	12	24	36	48	72	96	120	
Group 1													
272	0	0	1	2	3	2	3	-	-	-	-	-	
1598	0	0	1	3	3	1	1	1	0	0	0	0	
1594	0	0	1	2	3	1	3	1	0	0	0	0	
1597	0	0	1	2	3	1	1	1	0	0	0	0	
Group 2													
1748	0	0	2	3	3	2	1	1	0	0	0	0	
1599	0	0	1	3	3	1	1	1	0	0	0	0	
1600	0	0	3	3	2	2	-	-	-	-	-	-	
1731	0	0	1	3	3	1	1	0	0	0	0	0	
Control													
125	0	0	0	0	0	0	0	0	0	0	0	0	
128	0	0	0	0	0	0	0	0	0	0	0	0	
129	0	0	0	0	0	0	0	0	0	0	0	0	

0 - Normal, bright and alert, 1 - Slightly dull or depressed, easy to handle and hold, 2 - recumbent at first examination but rose on minimal stimulation, 3 - Very dull indeed, refused to rise or did so only after maximal stimulation

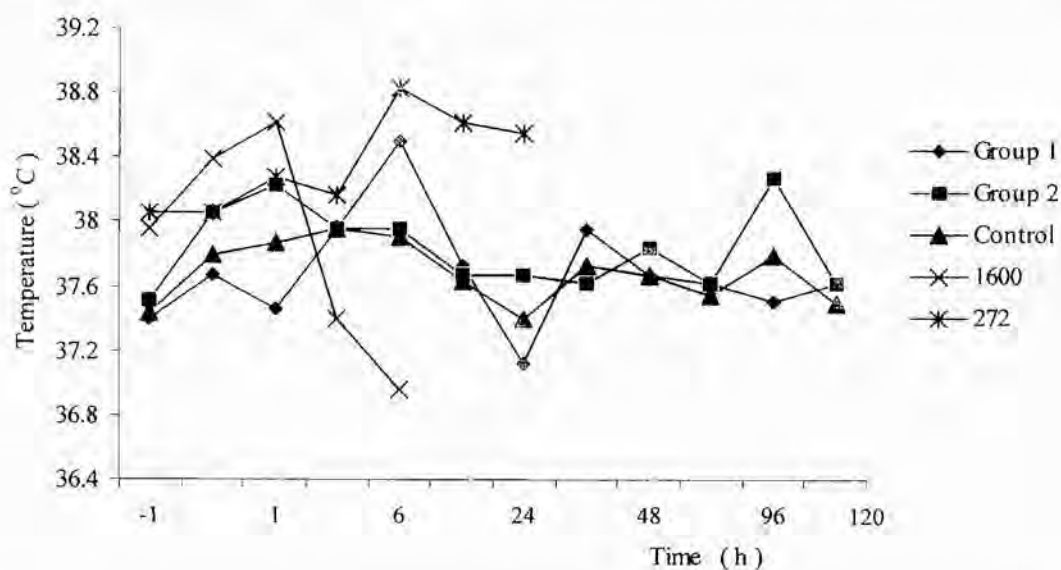


Figure 1. Rectal temperature changes in the LPS inoculated groups and the controls. The reading at each time point in Group 1, 2 and the controls represents the mean of three recordings. In the two animals (272 and 1600) that died, the data are shown separately.

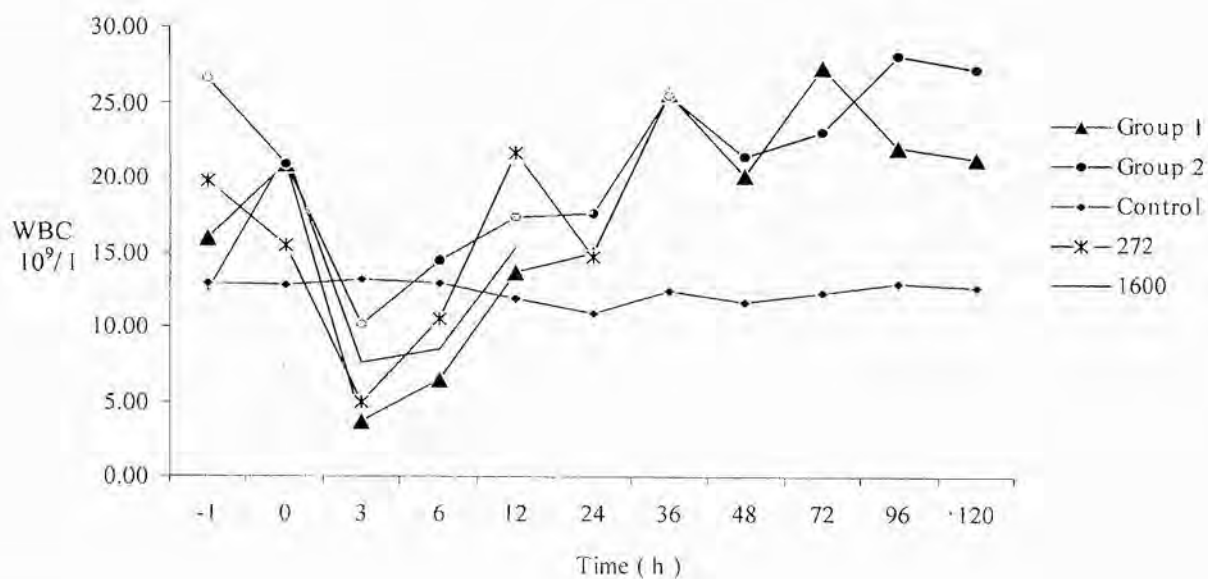


Figure 2. Total leucocyte counts in the LPS inoculated groups and the controls. The value at each time point in Group 1, 2 and the controls represents the mean of three recordings. In the two animals (272 and 1600) that died, the changes in the leucocyte counts are shown separately.



Figure 3. Severe oedema and congestion of the lungs following LPS inoculation (Animal No. 272).

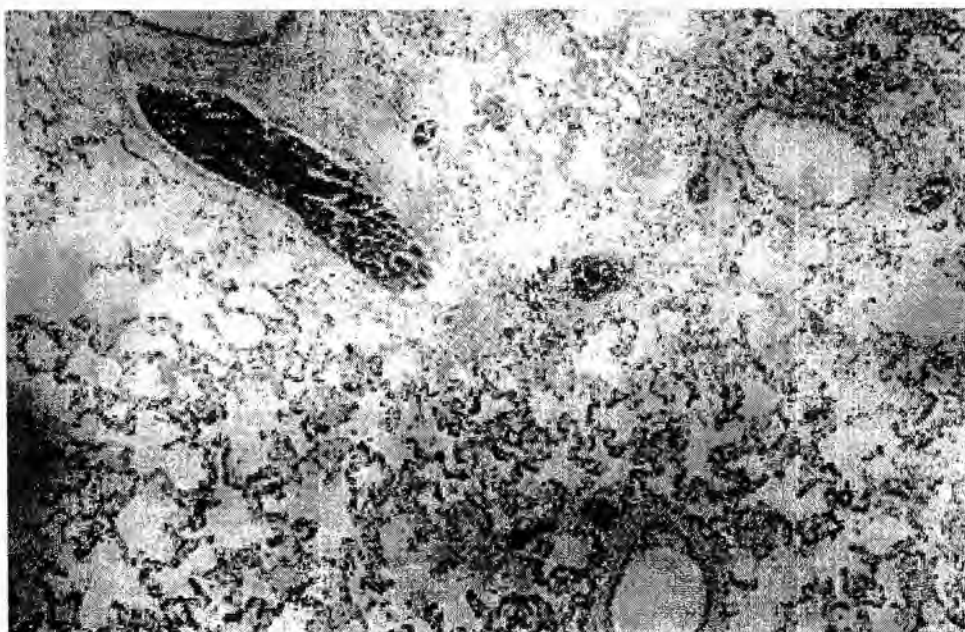


Figure 4. Histological section of the lungs in Figure 3, showing the congested blood vessels and the oedema fluid in the alveolar spaces.

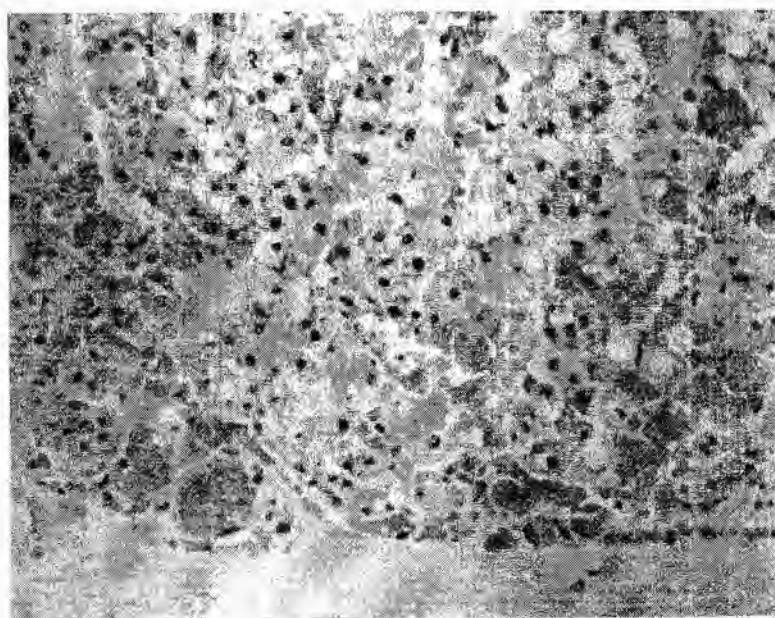


Figure 5. Histological section of the abomasal mucosa showing congested blood vessels and haemorrhage in the gastric mucosa.

The rectal temperature changes in buffalo calves following LPS administration was minimal when compared to those reported for other species, where a 2 to 3°C increase has been observed. This may reflect a species variation where protective mechanisms are present in the host to defend itself against the deleterious effects of bacterial LPS (Michaels and Banks, 1988). The leucocyte dynamics, characterised by the immediate leucopenia following LPS, may reflect the LPS-mediated leucocyte shift of cells from circulation to the marginal pool, while the subsequent leucocytosis could be a consequence to humoral stimulation of intramedullary granulopoiesis.

Many of the clinical and pathological responses to LPS noted in the present study are comparable to those observed in other species, where LPS is known to interact with numerous cell types and humoral mediator systems, resulting in a plethora of pathophysiological alterations causing multi-organ dysfunction and death (Olsen *et al.*, 1995). Necropsy findings such as pulmonary oedema, congestion of organs and haemorrhage in the alimentary tract are likely to be tissue manifestations to overstimulation by mediators such as the cytokine Tumour Necrosis Factor- α . Haemorrhage in visceral organs is likely to be a consequence to LPS-induced endothelial damage known to occur in bovines. The results of this study indicate that endotoxin, a virulence factor in many Gram-negative bacterial infections may play a significant role in the pathogenesis of HS caused by *P. multocida*. Indeed, this finding is likely to have major implications in future treatment and strategies used in the prevention of HS.

Acknowledgements

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ATTEMPTS TO ACTIVATE 'LATENT' CARRIERS OF HAEMORRHAGIC SEPTICAEMIA IN BUFFALO CALVES

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Abstract: Haemorrhagic septicaemia (HS) is a highly fatal septicaemic disease in buffaloes and the role of carrier animals in the epidemiology of the disease in endemic areas of Sri Lanka is well known. It was hypothesised that the ill-defined host factors termed 'stress', along with some environmental factors may influence the carriers to shed the virulent *Pasteurellae* that inhabit the nasopharynx. The carriers of HS, harbour *Pasteurellae* in the lumen of tonsils probably between outbreaks. However, detailed bacteriological examinations had revealed an intermittent nature in the appearance of organisms in the nasopharynx of clinically normal animals, and this observation had led to consideration of existence of two types of carriers, namely 'latent' and 'active' carriers.

In this study, attempts were made to activate experimentally produced 'latent' carriers to the secretory phase by simulating 'stress' by physical and chemical methods. The presence of virulent organisms in the nasopharynx was considered as an indication that these animals are 'active carriers'. Nasopharyngeal swabs were subjected to direct culture as well as for mouse inoculation, in order to demonstrate the presence of *Pasteurella multocida* in the nasopharynx.

The four attempts to induce 'stress' in buffaloes, namely by subjecting animals to tillage, walking or administration of long acting steroids (two dose rates), were made. These gave negative results to the mouse inoculation test, which is indicative of the absence of virulent *Pasteurella* in the nasopharynx. The paper concludes that the 'latent' carriers of HS cannot be activated using the methods described in this study. Further investigations are needed to find the molecular mechanisms of activation of carriers of HS and the role of 'stress' in field outbreaks.

Keywords: Haemorrhagic septicaemia, carriers, epidemiology, *Pasteurella multocida*, buffalo.

Introduction

Haemorrhagic septicaemia (HS) is a highly fatal, terminal septicaemic disease in cattle and buffaloes in Asia. It is considered to be the major cause of mortality in buffaloes, a species invaluable for the rural economy of the South East Asian region. Several authors have extensively reviewed the literature on HS (De Alwis, 1992; Wijewardana, 1992). The significance of carrier animals in the epidemiology of the disease is well established (De Alwis *et al.*, 1990; Wijewardana, 1986).

Pasteurella multocida serotype B:2 (Carter: Heddleston system) is the causative organism of HS in the Asian region. In endemic areas of Sri Lanka, the carrier rate is found to be around 2.7% (Hiranune *et al.*, 1982), with no significant difference between cattle and buffaloes. However, the carrier rate seems to be high just after an outbreak, which thereafter declines (De Alwis *et al.*, 1986). It is postulated that the *P. multocida* virulent organism is harboured by the carriers in between successive outbreaks (Wijewardana, 1992). Tonsils are the commonest site where the organisms were found (Wijewardana, 1986). Within the tonsils, *P. multocida* antigens were confined to the lumen of the tonsillar crypts (Horadagoda, 1990). Under experimental conditions, the longest period after initial exposure when *Pasteurellae* was detected in nasopharyngeal swabs was 215 days and recovery from tonsillar tissue was 229 days (De Alwis *et al.*, 1990).

The intermittent nature in the appearance of the organism in the nasopharynx of clinically normal animals has led to the consideration of the existence of two types of HS carriers. The first type, the 'latent' carrier, as indicated by high antibody titres, is believed to harbour the pathogen in the

tonsillar crypts, but are absent in the nasopharynx or in nasal secretions. The second type is the 'active' carrier, which is monitored by high antibody reactions and the presence of the organism in the nasopharynx, nasal secretions as well as in tonsils. It was assumed that ill-defined host factors termed 'stress' and some environmental factors may influence the 'latent' carriers to become secretory 'active' carriers of *Pasteurellae* (De Alwis, 1992). These findings led to the postulation that new outbreaks were initiated by activating 'latent' carriers, which disseminate the virulent organism into unexposed, non-immunized, susceptible livestock. Although there is no significant difference between cattle and buffaloes in carrier rates (De Alwis *et al.*, 1986), buffaloes seem to be more susceptible to the clinical disease than cattle (Wijewardana, 1992).

The objective of the present study was to activate, experimentally produced 'latent' carriers to the secretory phase by simulating the natural phenomenon of 'stress' by different methods.

Materials and Methods

Nine buffalo calves housed at the Veterinary Research Institute were experimentally inoculated with the 33S strain of *P. multocida* in order to produce 'latent' carriers, according to the method described (De Alwis *et al.*, 1990). The carrier status of these animals were monitored throughout the experimental period by (a) assaying blood samples twice weekly for antibody titres using the Indirect Haemagglutination technique (IHA) and (b) attempting to isolate *P. multocida* in nasopharyngeal swabs tested by mouse inoculation. The following methods were used to induce stress.

Method 1: Simulated tillage/land preparation activity.

A muddy field was constructed and four of the carriers were made to walk in the mud for 2 consecutive days spending 8 hours continuous on each day. Nasopharyngeal swabs and salivary secretions were collected 6 hourly for 3 consecutive days.

Method 2: Walking long distances

Four animals were made to walk a distance of 80 km for 12 h with provision of limited food and water. Nasopharyngeal swabs were taken every 6 hours for 3 consecutive days.

Method 3: Immune-suppression with Dexamethasone sodium phosphate

A total dosage of 40mg of Dexamethasone sodium phosphate (Dexona; Cadila) was given to each animal intramuscularly, in single administration. Nasopharyngeal swabs were taken every 12 hours on 3 consecutive days.

Method 4: Immune-suppression with Methylprednisolone acetate

Methylprednisolone acetate (Depo-Medrol; Upjohn) as a total dose of 200 mg was given to each animal intramuscularly, in single administration. After 72 hours, neostigmine methyl sulphate (Prostigmin; Roche) was given in divided doses, i.e. 5mg intravenous and 15 mg intramuscularly. Nasopharyngeal swabs were taken every 6 hours for 3 consecutive days. The collected saliva and swabs were tested for virulent *Pasteurellae* by mouse inoculation and direct plate culture methods.

Results

Eight of nine buffalo calves became 'latent' carriers as indicated by IHA titres. During a one-year experimental period, carriers had fluctuating IHA titres ranging from 5120 to 20. In all four experiments swabs were negative for virulent *P. multocida* as indicated by mouse inoculation test.

Methods 1 and 2

Animals became tired exhibiting high temperature and some degree of salivation.

Method 3

Animals had a high temperature showing some degree of salivation without any signs of disease or secretory *Pasteurellae*.

Method 4

After neostigmine injections, animals showed profuse salivation for 4 hours. The virulent *P. multocida* was not isolated from the saliva collected and mouse inoculation tests were negative for virulent organisms.

Discussion

Prolonged or intense stimuli perceived by an animal is defined as stressors (Stephens, 1980), while resultant homeostatic, physiological and behavioural responses are termed as stress (Ganong, 1993). During stress, there is elevated glucocorticoid level, mediated through adrenocorticotrophic hormone. This is accompanied by increased secretion of catecholamines and an elevated blood glucose concentration (Ganong, 1993).

Well known stressors in the bovine include extremes of temperature, excessive exercise and long distance transportation. The Asian buffalo is a dual purpose animal (draught and milk) which is subjected to above mentioned stressors during paddy cultivation (de Silva *et al.*, 1985). Although the corticosteroid levels were not measured in this study, every attempt was made to simulate the field practice of using buffaloes in paddy cultivation. Throughout the experimental periods, the maintenance of high antibody titres was considered as an indicator for the presence of 'latent' *Pasteurellae* in tonsils. In spite of frequent examination of swabs, *Pasteurella* was not isolated from the nasopharynx during experimental periods.

The failure to isolate the virulent *Pasteurellae*, led to further consideration of the tonsillar gland and nasopharynx. Of the three main tonsils (Junquera *et al.*, 1998), the palatine tonsil situated on the lateral wall of pharynx had been the common location for *Pasteurellae* (Wijewardana, 1986). Microscopically, the palatine tonsil consists of deep surface invaginations referred to as tonsillar fossulae, which communicate with the mouth cavity through a tonsillar sinus. In the absence of profuse salivary secretions, the fossulae may get obstructed with desquamated epithelial cells, live or dead lymphocytes and bacteria (Chen *et al.*, 1991; Junquera *et al.*, 1998). Administration of the parasympathomimetic drug, neostigmine (Prostigmin; La Roche) is expected to dilate the tonsillar sinus, as well as increase salivary secretion. Thus it was expected to wash out any virulent *Pasteurellae*, if they were harboured in the crypts of the tonsil. Attempts to isolate the pathogen from collected saliva following neostigmine medication and also from nasopharyngeal swabs by mouse inoculation proved to be negative for virulent *Pasteurellae*.

Immune-suppression is an important consequence of elevated corticosteroid levels during stress. The influence of antibody concentration depends on the type of glucocorticoid administered, dosage and frequency of administration. Dexamethasone at different dose rates (varying between 20 - 60 mg total dose) had been successfully used in activating coccidiosis (Stockdale and Nilo, 1976; Nilo, 1970) and herpes virus (Sheffy and Davis, 1972). Since immunosuppressive doses in buffaloes were not established, in the first experiment, the dose of 40 mg per animal was administered intramuscularly which proved to be ineffective. Methyl prednisolone acetate is a slow release product which produces a long acting immuno-suppressive effect at an equivalent dose rate used in human, that is 40 - 120 mg per individual (BNF, 1997). For the same purpose, the dose used in horse is 200 mg per animal (Bishop, 1998) which was used in the present study.

in buffalo calves. Although there was no activation of 'latent' *Pasteurellae*, fluctuating IHA titres were indicative of some degree of immunosuppression. The lack of confirmatory evidence of the carrier status by isolating virulent *Pasteurella multocida* from tonsillar glands after post-mortem examination, was a deficiency in the present study.

However, this study clearly demonstrates the relative difficulty in activating 'latent' carriers of HS under experimental conditions in buffalo calves. Cattle may react differently. This needs further consideration. If HS carriers among cattle react differently to buffaloes, such information will be a valuable contribution to the understanding of the epidemiology of HS.

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MASTITIS, BRUCELLOSIS AND RINDERPEST IN BUFFALOES IN SRI LANKA: A COMPARISON WITH CATTLE

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Abstract: *Mastitis:* The somatic cell counts (SCC), electrical conductivity, adenosine triphosphate (ATP) and chloride ion concentrations are markers of subclinical mastitis in the buffalo. The SCC in buffalo is similar to cattle, but the count and the efficiency of milk neutrophils (phagocytes) are superior in the buffalo. In contrast to cattle, the buffalo is more resistant to udder infections, particularly to *Staphylococcus aureus* infections, due to the more efficient removal of *S. aureus* by buffalo neutrophils (BN); the activity of BN in milk is similar to their blood counterpart. However, the bactericidal activity of BN and cattle neutrophils (CN) following phagocytosis appears to be greater for *E. coli* relative to *S. aureus* and *Strep. agalactiae*. In mixed bacterial cultures, BN and CN preferentially phagocytize one bacterial species *in vitro*; the affinity of BN for *E. coli* was less in the presence of *S. aureus* or *Strep. agalactiae*; affinity of CN for *S. aureus* was less in the presence of *E. coli*, while the affinity for *E. coli* was less in the presence of *Strep. agalactiae*.

Brucellosis: Seroprevalence for *Brucella abortus* is not different among unvaccinated buffaloes (4.2%) and cattle (4.7%). Buffaloes and cattle in the dry zone (annual rainfall from 20-30 inches) and those which were managed extensively were more often seropositive. Older (>3 years) buffaloes and cattle were at higher odds of being seropositive, and they show clinical signs suggestive of brucellosis in almost equal proportions.

Rinderpest: Seroprevalence for rinderpest virus is not substantially different among unvaccinated buffaloes (5.3%) and cattle (3.1%). In general, older bovids (>3y) were more often seropositive and among them the buffaloes were at higher odds of being seropositive than cattle.

Keywords: Mastitis, buffalo, cattle, rinderpest, brucellosis, seroepidemiology

Introduction

This report is a summary of studies done by the authors on mastitis, brucellosis and rinderpest in buffaloes and cattle in Sri Lanka. Mastitis is the greatest single cause of loss of milk in the dairy industry. Although buffaloes are resistant to mastitis relative to cattle, udder infections can cause serious losses in large buffalo herds (Silva, 1996; Wanasinghe, 1985). Most subclinically affected buffalo quarters did not yield bacteria on culture, while streptococci and staphylococci were the major bacteria isolated from the rest (Silva *et al.*, 1996). An efficient defense mechanism in the mammary gland is critical to the cow's ability to survive an infection and return to normal production. This defense mechanism consists of conformational changes in the streak canal, immunoglobulins, phagocytes and their products (Silva, 1996). As bacteriological testing of all cows in a herd is cumbersome and expensive, it is a standard practice to monitor indicators of mastitis at herd level (Silva *et al.*, 1996). One objective of this report is to describe the markers of mastitis in buffalo milk and to compare the efficiency of the buffalo in the removal of invading bacteria relative to cattle.

Brucellosis is essentially an infectious disease of the sexually mature animals (females and males) and is also a zoonotic disease. The first case of bovine brucellosis in Sri Lanka was first reported in 1956 and the biotype 3 of *Brucella abortus* has been reported as the causative organism (Kumaraswamy, 1971). A large-scale control programme had never been considered in Sri Lanka. While vaccination has not been practised for over ten years in state-owned farms, control programmes have never been implemented in privately owned herds.

Rinderpest is an extremely contagious disease which cause immense economic losses in livestock farming in many Asian and African countries (Ojok and Mariner, 1996; Scott, 1981). Sri Lanka had been declared free of rinderpest since 1946, until the outbreak in 1987 in the eastern province in the

dry zone (Vadivelu, 1989). Despite control measures adopted, rinderpest has been established in an endemic form in the dry zone during the period from 1990-1993 (Hettiarachchi and Sriharan, 1996).

The other objective of this study was to describe the seroprevalence and the potential risk factors of brucellosis and rinderpest in buffaloes in Sri Lanka with a comparison to cattle.

Materials and Methods

Markers of mastitis

The buffaloes and cattle, milk samples, techniques used and statistical analyses are described in detail elsewhere (Silva *et al.*, 1996). The somatic cell count (SCC), differential cell counts, electrical conductivity (EC), chloride percentage (Cl%), acidity and ATP concentration were measured in normal and mastitic milk.

Functional efficiency of neutrophils

The buffaloes, the isolation of cells from blood and milk, the preparation of bacterial cultures, the phagocytic assays and microscopic evaluation, and the statistical analyses are described in detail elsewhere (Silva, 1996; Silva and Kariyawasam, 1996; Silva, 1993a; Silva, 1993b). The same details for cattle is described in Silva and Jain, 1988. The methodology used to study the preferential phagocytosis of bacteria in mixed cultures by buffalo and cattle cells are described in detail in Silva and Thattai, 1995 and Silva *et al.*, 1988, respectively.

Brucellosis and Rinderpest

Approximately, 0.2% of the bovids (cattle and buffalo) in Sri Lanka was sampled, from June 1992 to 1995 using a multi stage sampling procedure. Serum antibodies for *Brucella abortus* and the rinderpest virus were detected using the Indirect Enzyme Linked Immunosorbent Assay (IELISA) and Competitive Enzyme Linked Immunosorbent Assay (CELISA), respectively. The age, the agroecological zones and the management system practised in the farms of the sampled bovids were studied as potential risk factors for being seropositive for the two diseases, separately. All details of the two studies are described in Silva *et al.*, (2000) and in Silva *et al.*, (1998).

Results

Mastitis

The SCC in buffalo milk ranged from 50,000-375,000/ml and 56% (22-88%) of those were neutrophils. The bacteria isolated from milk samples from subclinically infected quarters were coagulase negative staphylococci (22%), *Streptococcus uberis* (15%), *Streptococcus agalactiae* (11%) and other streptococci (7%). About 44% of the samples did not yield any bacterial growth. During mastitis the SCC in buffaloes increased between 0.5×10^6 - 75×10^6 /ml. The EC of normal buffalo and cattle milk ranged from 3.4-4.8 (3.9) milli Siemens/cm and 3.7-5.1 (4.6) milli Siemens/cm, respectively. In mastitis, the EC significantly elevated to 4.9 (3.9-5.7) milli Siemens/cm in buffaloes and to 5.4 (4.0-7.2) milli Siemens/cm in cattle. The Cl% of normal buffalo and cattle milk ranged from 0.08-0.2 (0.11) and 0.1-0.16 (0.13), respectively. In mastitis, the Cl% significantly elevated to 0.14 (0.11-0.21) in buffaloes and to 0.18 (0.1-0.35) in cattle. Significant changes were not seen in acidity % and pH between normal and mastitic milk. The mean ATP concentration in normal buffalo milk was 5×10^{-10} moles/ml and the levels increased significantly between each increasing CMT score (10.0 - 32.7×10^{-10} moles/ml).

The percent phagocytosis (PP), or the number of neutrophils which performed active phagocytosis, was highest for *Staphylococcus aureus* (86-88%). The PP for *S. aureus* was statistically similar to that

of *Streptococcus agalactiae* (77-81%) and was significantly higher than that for *Escherichia coli* (73-78%) (Silva, 1996; Silva, 1993a). The PP of cattle neutrophils for the same bacterial strains was high for *E. coli* (81%) and *Strep. agalactiae* (77%) followed by *S. aureus* (63.6%) (Silva and Jain, 1988).

Brucellosis

The median number of farms visited per district was 35 (range 15-122). A total of 3916 bovids (3076 cattle and 840 buffaloes) from private herds from 102 of 266 Divisional Secretariat Areas (DSAs) in 22 of 25 districts were bled during June 1992 to August 1995. Three districts were not sampled due to security problems that prevailed during that period. More than 0.1% of the bovid population in every district was sampled, except in 3 districts. The male:female ratio of the bovids sampled was 1:4.3 in cattle and 1:2.5 in buffaloes. The breeds of cattle in the study were local (62%), European (7%) and European crosses (2%), and the breeds of buffaloes were local (74%), Murrah (1%), Niliravi (0.7%) and their crosses (25%).

The overall seroprevalence of *B. abortus* in bovids was 4.6% (95% CI=3.4, 6.0). The prevalence was 4.7% in cattle and 4.2% in buffaloes ($\chi^2=0.5$; df=1); and 3.6% in males and 4.9% in females ($\chi^2=2.5$; df=1). Most seropositive males (22 of 29) were from the dry zone (annual rainfall from 20-30 inches) and were extensively managed. Bovids more than 3 years of age were at 2 times higher odds of being seropositive compared to those that were ≤ 3 years as were females when analyzed separately (OR=2.4; 95% CI=1.6, 3.5). There was no difference in seropositivity between cattle and buffaloes in the two age groups. Bovids from the dry zone were approximately at five times higher odds of being seropositive compared to those from the other zones (females only: OR=5.1; 95% CI=3.0, 7.8). There was no difference in seropositivity between cattle and buffaloes in the two agroecological zones. Bovids reared under extensive management system were at approximately two times higher odds of being seropositive compared to those that were reared under other management systems (females only: OR=1.8; 95% CI=1.2, 2.6). There was no difference in seropositivity between cattle and buffaloes in the different management systems. The prevalence in bovids in the dry zone managed extensively was 11% (95% CI=7.3, 15.1; n=982) compared to 1.9% (95% CI=0.8, 3.7; n=183) in other management systems. Bovids from the dry zone were found to be at approximately six times higher odds of being seropositive, after adjusting for the possible confounding effects of age and management methods practised (Mantel-Haenszel weighted OR=6.3; 95% CI= 4.2, 8.9).

Bovids with a history of abortion were at higher odds of being sero-positive compared to those without a history of abortion (OR=18.3; 95% CI=10.9, 30.6). Only 49% and 36% of the aborted cattle and buffaloes, respectively, were seropositive ($\chi^2=1.6$, df=1). Among the seropositive females >3 years old, 25% of the cattle and 40% of the buffaloes had aborted at least once. None of the sampled bovids with a history of repeat breeding had detectable levels of antibodies. Twenty three bovids were reported to have shown other clinical signs suggestive of brucellosis, and only 5 of them were seropositive.

Rinderpest

The median number of farms visited per district was 36 which varied between 15-122. A total of 4397 bovids (3489 cattle and 908 buffaloes) from private herds in 102 of 266 DSAs from 23 of 25 districts had been bled during the period from June 1992 to August 1995. The breeds of cattle included in the sample were local, European, zebu and their crosses, and the breeds of buffaloes were local, Indian and their crosses.

The sero prevalence of bovids which were never vaccinated (n=4101) and those which had been vaccinated (n=296) against rinderpest were 3.5% and 12.5%, respectively. The prevalence was 3.1% in cattle and 5.3% in non-vaccinated buffaloes. Among the non-vaccinated bovids, those that were >3 years of age were at approximately five times higher odds of being sero-positive compared to those that were ≤ 3 years {OR=4.8 (3.0-7.8); $\chi^2=56.3$ }. A similar relationship between age and sero-

positivity was noticed among the vaccinated bovids, although the strength of association was less. Buffaloes >3 yr were at two times higher odds of being seropositive relative to cattle {OR=2.3 (1.5-3.6); $\chi^2=17.6$ }. Non-vaccinated bovids from the dry zone were at approximately eleven times higher odds of being sero-positive {OR=11.5 (7.2-18.6)} compared to those from the other zones. A similar relationship was noticed in the vaccinated bovids although the strength of association was less (OR=3.6). There was no difference in seropositivity between cattle and buffaloes in the two agroecological zones.

Non-vaccinated bovids reared under extensive management system were at approximately five times higher odds of being sero-positive {OR=4.5 (2.7-7.7)} compared with those that were reared under other management systems. There was no difference in seropositivity between cattle and buffaloes in the different management systems.

Those bovids from the dry zone were found to be at approximately eight times higher odds of being sero-positive, after adjusting for the effects of age, vaccination history and management methods practised (Mantel-Haenszel weighted OR= 7.66; 95% CI=5.48- 13.13).

Discussion

Mastitis

The SCC and the different types of cells in buffalo milk are similar to those in cattle milk. Neutrophils are the most prominent cells in buffalo milk (Silva and Silva, 1994). The presence of cells undergoing necrosis (2%) in buffalo milk suggests that their milk leukocytes are functionally more active than cattle cells. The SCC, EC, CI% and ATP concentrations are valuable markers or indicators of subclinical udder infections in buffaloes. Although the buffalo SCC is similar to cattle, the concentration and functional efficiency of milk phagocytes is superior in buffaloes (Silva 1993a and b). An elevation of more than the mean plus twice the standard deviation in EC ($3.87+(2 \times 0.3)=4.47$ mS/cm) of the normal milk, when measured individually for each buffalo, can be used as an indicator of subclinical mastitis in buffaloes. Elevations in EC and CI% precede that of the SCC.

The phagocytic activity of buffalo blood neutrophils was 22.5% higher, while that of milk neutrophils was 17% higher for *S. aureus* than cattle cells (Silva 1996). These findings explain the resistance of buffaloes to mastitis caused by *S. aureus* (Wanasinghe, 1985). A relatively higher bactericidal activity was observed for *E. coli* (Silva and Kariyawasam, 1996). Streptococcal species were the major mastitis causing bacteria isolated in subclinically infected buffaloes in Sri Lanka. When buffaloes are exposed to mixed bacterial infections a poor preference was shown for *E. coli*, and this affinity for *E. coli* was much less in the presence of *S. aureus* than *Strep. agalactiae*. Cattle neutrophils also demonstrated a low preference for phagocytizing *E. coli* in the presence of *Strep. agalactiae*, but not *S. aureus* (Silva *et al.*, 1988). The age of the phagocytes in milk, the microorganisms involved or their metabolic products appear to play a major role in the defense against mastitis. In contrast to cattle, the phagocytic efficiency of the neutrophils which appear in milk during acute subclinical mastitis in buffaloes was superior. These findings reveal the potential of reducing bacterial mastitis in buffaloes by improving the phagocytic activity of milk neutrophils. This may be achieved by enhancing the opsonin concentration in milk perhaps by vaccination.

Brucellosis

The seroprevalence of brucellosis was not substantially different between cattle (4.7%) and buffaloes (4.2%). Because none of the animals in this study were vaccinated, the seropositivity was considered to be due to exposure to natural infection (Silva *et al.*, 2000). However, even if the bovids were vaccinated, the residual titres should not have interfered with the test result, because vaccinal titres cannot be detected 22 weeks after vaccination (Pieris *et al.*, 1983).

As expected, the seroprevalence of bovids over 3 years of age was twice as high as the younger age group because brucellosis is essentially a disease of mature animals. Seropositivity was more often found in the dry zone and also when animals were reared under extensive management system. There was a true effect of the agroecological zone on the prevalence even after controlling for the possible effects of age and management system. Approximately 75% of the seropositive males were from the dry zone. A majority (84%) of bovids from the dry zone in this study were reared under an extensive management system (free grazing) which allows unrestricted contact between animals. These factors would have enhanced the spread of brucellosis in bovids in the dry zone.

Brucellosis could be an important cause of abortion in bovids in Sri Lanka. As expected, seropositive cattle and buffaloes do not differ in their histories of abortion. Investigations should be carried out to identify causes for about 50% of abortions in cattle and buffaloes. The IELISA used in this study, positively detects animals which are negative with the conventional tests used in Sri Lanka, such as those animals with persisting low titres.

Rinderpest

The prevalence of rinderpest in bovids due to natural exposure could be taken as 3.5% which is the prevalence in non-vaccinated bovids. Most of the seropositive non-vaccinated cattle and buffaloes (84%) were from the dry zone of the country, which is most likely due to the location of the outbreak in 1987. The higher prevalence in older animals is probably due to exposure to the virus during the 1987 epidemic. Furthermore, 62% of the bovids from the dry zone were reared under the extensive management system which would have enhanced the spread of rinderpest in the dry zone leading to a higher prevalence. Bovids from the dry zone were at higher odds of being sero-positive even after controlling for the possible effects of age, agroclimatic zone, management system and vaccination. A relatively poor response to vaccination (seroprevalence=12%; n=296) could be attributed to difficulties in maintaining the vaccine at recommended temperatures in the field. The CELISA used in this study, which is not a conventional test in Sri Lanka, has been used in rinderpest eradication programmes in Africa and Asia because of its suitability for both seromonitoring and serosurveillance due to its ability to detect antibodies to a range of rinderpest virus strains.

Conclusions

The SCC, electrical conductivity, ATP and chloride % are markers of subclinical mastitis in the buffalo. The SCC in buffalo is similar to cattle but the count and the efficiency of milk neutrophils (phagocytes) are superior in the buffalo. In contrast to cattle, buffalo is more resistant to udder infections, particularly to *Staphylococcus aureus* infections. In mixed bacterial cultures, the affinity of buffalo neutrophils for *E. coli* was less in the presence of *S. aureus* or *Strep. agalactiae*; affinity of CN for *S. aureus* was less in the presence of *E. coli*.

Seroprevalence for *Brucella abortus* is not different among unvaccinated buffaloes (4.2%) and cattle (4.7%). Buffaloes and cattle in the dry zone and those which were managed extensively were more often seropositive. Older (>3 years) buffaloes and cattle were at higher odds of being seropositive, and they show clinical signs suggestive of brucellosis in almost equal proportions.

Seroprevalence for rinderpest virus is not substantially different among unvaccinated buffaloes (5.3%) and cattle (3.1%). In general, older bovids (>3y) were more often seropositive and among them the buffaloes were at higher odds of being seropositive than cattle.

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MEDETOMIDINE AS A SEDATIVE IN BUFFALO CALVES

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Abstract: Medetomidine is a very potent sedative and selective α_2 agonist. The sedative/analgesic effects of three dose rates of medetomidine hydrochloride (5 μ g/kg, 8 μ g/kg and 10 μ g/kg) were studied in six healthy male buffalo calves. Moderate to deep sedation occurred after intravenous administration of 8 μ g/kg and 10 μ g/kg of medetomidine as compared to slow and light sedation produced by 5 μ g/kg. The degree, onset and duration of sedation and onset and duration of maximum sedation were all dose dependent. Skin analgesia and light muscle relaxation were produced in all animals with higher doses (8 μ g/kg and 10 μ g/kg) and in only one animal with a lower dose (5 μ g/kg). Medetomidine produced recumbency in all animals with high doses (8 μ g/kg and 10 μ g/kg) and in 50% of animals with the lower dose (5 μ g/kg). The duration of recumbency was 29.33 min, 50.17 min and 73.5 min and standing time was 33.67 min, 53.5 min and 76 min after administration of 5 μ g/kg, 8 μ g/kg and 10 μ g/kg medetomidine respectively.

Keywords: Buffalo, medetomidine hydrochloride, sedation, dose response, analgesia

Introduction

Many surgical procedures in cattle and buffaloes can be performed with physical restraint and under local, regional anesthesia and sedation. The fear of performing general anesthesia is generally greater amongst veterinarians, when dealing with a bovine patient. For economic reasons and the evidence of some adverse effects produced by general anesthesia, many minor surgical procedures in cattle and buffaloes are usually performed under sedation and local anesthesia.

The development of sedatives/analgesics in recent years has greatly contributed to the progress made by the veterinary profession. These developments have resulted in a reduction of stress, prevention or control of pain and achieving safe and efficient anesthesia. α_2 adrenergic agonist and antagonist have a significant role in this development of patient care (Short, 1992). α_2 agonists are a particularly useful part of the veterinarian's armamentarium because they combine sedation with analgesia. α_2 agonists also have intrinsic muscle relaxation properties (although not of the quality produced by general anesthesia) (Thurmon *et al.*, 1996).

Medetomidine is a very potent and selective α_2 agonist. It is approved in USA for use in dogs (Anon., 1996). There are some reports of its use in sheep, goat and cattle and in laboratory and wild animals (Muhammad *et al.*, 1989; Mohammad *et al.*, 1993). It has also been used in combination with other drugs (Hall and Clarke, 1991). The objective of this study is to examine the effects of medetomidine as a sedative in buffaloes.

Material and Methods

The subjective observations of the behaviour of animals and the degree and the nature of sedation and analgesia after the injection of medetomidine were recorded. The degree of sedation was graded as 0 for no sedation (slight effect with the animal becoming quieter and easier to handle), 2 for moderate sedation (animal becoming less alert, partial closure of eyelids, less responsive to external stimuli or noise) and 3 for deep sedation (animal becoming ataxic and recumbent). The analgesic effect was noted by the absence of a response to deep needle pricking and deep scalpel incision. The onset of sedation, the beginning of maximum sedation, duration of maximum sedation and start of recovery were recorded after the injection of medetomidine. The other signs,

such as the onset of recumbency, the duration of recumbency, standing time, salivation, regurgitation, lacrimation, urination, defaecation, snoring, bellowing, tympany and protrusion of the tongue were also noted. The palpebral and pedal reflexes, nystagmus and inward rolling of eyeballs, drooping of head, animal behaviour, posture and gait were also recorded.

Results

Onset of sedation

The mean values for the onset of sedation were 185 seconds, 63.33 seconds and 40.83 seconds after administration of 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine, respectively (Table 1). The onset of sedation was dose dependant with higher doses producing a more rapid onset. Analysis of variance showed that the onset of sedation was significantly different ($P<0.01$) with all three doses. Further analysis by Turkey-Kramer Multiple Comparison Test showed that the onset of sedation was significantly rapid ($P<0.01$) with 8 µg/kg and 10 µg/kg as compared to 5 µg/kg. There was no significant difference in the onset of sedation with 8 µg/kg and 10 µg/kg of medetomidine.

Table 1. Onset of sedation in buffalo calves after administration of different doses of medetomidine (in sec.)

Animal No.	Medetomidine 5 µg	Medetomidine 8 µg	Medetomidine 10 µg
1	60	30	15
2	120	60	30
3	180	20	60
4	300	60	50
5	240	120	60
6	210	90	30
Mean	185 ππ++	63.33++	40.83ππ
SEM	35.00	15.202	7.574

++ = significant difference at ($P<0.01$) between values of 5 µg and 8 µg.

ππ = significant difference at ($P<0.01$) between values of 5 µg and 10 µg.

Table 2. Onset of maximum sedation in buffalo calves after administration of different doses of medetomidine (in min.).

Animal No.	Medetomidine 5 µg	Medetomidine 8 µg	Medetomidine 10 µg
1	10	5	2
2	4	3	2
3	5	4.5	3
4	7	6	1.5
5	6	3	2.5
6	5	3.5	3
Mean	6.16 ππ	4.16	2.33ππ
SEM	0.872	0.494	0.247

ππ = significant difference at ($P<0.01$) between values of 5 µg and 10 µg.

Onset of maximum sedation

The mean values for onset of maximum sedation were 6.16 min, 4.16 min and 2.33 min after administration of 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine, respectively (Table 2). The onset of maximum sedation was dose dependent. The onset was more rapid with increasing dose rate. Analysis of variance showed that the onset of maximum sedation was significantly different ($P<0.01$) with all doses. Further analysis by Turkey-Kramer Multiple Comparison Test showed that the onset of maximum sedation was significantly rapid ($P<0.01$) with 10 µg/kg as compared

to 5 µg/kg. Comparison of 5 µg/kg with 8 µg/kg and 8 µg/kg with 10 µg/kg showed no significant difference in onset of maximum sedation.

Duration of maximum sedation

The mean values for duration of maximum sedation were 4.41 min, 25.66 min and 39 min after administration of 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine respectively (Table 3). The duration of maximum sedation was dose dependent. Analysis of variance showed that the duration of maximum sedation was significantly different ($P<0.01$) with all three doses. Further analysis by Turkey-Kramer Multiple Comparison Test showed that the duration of maximum sedation was significantly longer ($P<0.01$) with 8 µg/kg and 10 µg/kg as compared to 5 µg/kg. There was no significant difference in the duration of maximum sedation with 8 µg/kg and 10 µg/kg of medetomidine.

Table 3. Duration of maximum sedation in buffalo calves after administration of different doses of medetomidine (in min.).

Animal No.	Medetomidine	Medetomidine	Medetomidine
	5 µg	8 µg	10 µg
1	8	45	48
2	6	13	34
3	5	30	27
4	2	26	44
5	3	22	39
6	2.3	18	42
Mean	4.41 $\pi\pi$ ++	25.66++ Δ	39 $\pi\pi\Delta$
SEM	0.952	4.566	.077

++ = significant difference at ($P<0.01$) between values of 5 µg and 8 µg.

$\pi\pi$ = significant difference at ($P<0.01$) between values of 5 µg and 10 µg.

Δ = significant difference at ($P<0.01$) between values of 8 µg and 10 µg.

Total duration of sedation

The mean values for total duration of sedation were 40 min, 90.83 min and 105 min after administration of 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine respectively (Table 4). The total duration of sedation was dose dependent. The total duration was increased with increasing dose of medetomidine. Analysis of variance showed that the total duration of sedation was significantly different. Further analysis by Turkey-Kramer Multiple Comparison Test showed that total duration of sedation was significantly longer ($P<0.01$) with 8 µg/kg and 10 µg/kg as compared to 5 µg/kg. There was no significant difference in total duration of sedation with 8 µg/kg and 10 µg/kg of medetomidine.

Table 4. Total duration of maximum sedation in buffalo calves after administration of different doses of medetomidine (in min.).

Animal No.	Medetomidine	Medetomidine	Medetomidine
	5 µg	8 µg	10 µg
1	45	105	85
2	44	96	120
3	40	95	110
4	35	77	98
5	38	88	103
6	38	84	114
Mean	40 $\pi\pi$ ++	90.83++	105 $\pi\pi$
SEM	1.571	4.045	5.112

++ = significant difference at ($P<0.01$) between values of 5 µg and 8 µg.

$\pi\pi$ = significant difference at ($P<0.01$) between values of 5 µg and 10 µg.

Degree of sedation

The degree of sedation was light in all animals with 5 µg/kg of medetomidine. With 8 µg/kg four animals (Nos. 3, 4, 5 and 6) were in moderate sedation and one animal each was in deep and light sedation. With 10 µg/kg of medetomidine, four animals (Nos. 1, 4, 5 and 6) showed signs of deep sedation and two animals (Nos. 2 and 3) were in moderate sedation (Table 5).

Table 5. Degree of sedation in buffalo calves after administration of different doses of medetomidine.

Animal No.	Medetomidine 5 µg	Medetomidine 8 µg	Medetomidine 10 µg
1	1	3	3
2	1	1	2
3	1	2	2
4	1	2	3
5	1	2	3
6	1	2	3
Mean	1	2	2.66
SEM	0.00	0.258	0.211

1 = Light sedation

2 = Moderate sedation

3 = Deep sedation

Analgesia

Skin analgesia was produced in all animals with higher doses (8 µg/kg and 10 µg/kg) of medetomidine and in only one animal with lower dose (5 µg/kg).

Onset of recumbency

The dose rate of 5 µg/kg induced recumbency in half of the animals studied (Nos. 1, 2 and 5), whereas higher doses (8 µg/kg and 10 µg/kg) induced recumbency in all animals (Table 6). The mean values for onset of recumbency were 4.33 min, 3.33 min and 2.50 min after administration of 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine respectively. The onset of recumbency was similar with all three doses and this effect was not dose dependent.

Duration of recumbency

The duration of recumbency was 29.33 min, 50.17 min and 73.5 min after administration of 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine respectively (Table 6). The duration of recumbency was dose dependent in that the duration increased with increased medetomidine. Analysis of variance showed that the duration of recumbency was significantly different with three doses studied. Further analysis by Turkey-Kramer Multiple Comparison Test showed that the duration of recumbency was longer ($P < 0.01$) with 10 µg/kg as compared to 5 µg/kg. There was no significant difference in the duration of recumbency with 8 µg/kg and 10 µg/kg of medetomidine.

Standing time

The mean values for standing time were 33.67 min, 53.5 min and 76 min with 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine, respectively (Table 6). There was dose dependent effect of medetomidine on standing time. The dose rate of 10 µg/kg resulted in a longer standing time (76 min) followed by 8 µg/kg (53.5 min) and 5 µg/kg (33.67 min).

Table 6. Recumbency and standing time (minutes) in buffalo calves after administration of different doses of medetomidine.

Animal No.	Medetomidine 5 µg			Medetomidine 8 µg			Medetomidine 10 µg		
	Onset of Recumbency	Duration of Recumbency	Standing time	Onset of Recumbency	Duration of Recumbency	Standing time	Onset of Recumbency	Duration of Recumbency	Standing time
1	4	26	30	2	95	97	3	70	73
2	4	42	46	2	50	52	1	108	109
3	No	No	No	3	64	67	2	62	64
4	No	No	No	6	29	35	3	43	46
5	5	20	25	4	30	34	2	85	87
6	No	No	No	3	33	36	4	73	77
Mean	4.33	29.33**	33.67 $\pi\pi$	3.33	50.17	53.5	2.5	73.5**	76 $\pi\pi$
S.Error	0.33	6.56	6.33	0.61	10.56	10.17	0.42	8.94	8.68

** = significant difference at (P<0.01 level) between values of 5 µg and 10 µg.

$\pi\pi$ = significant difference at (P<0.01 level) between values of 5 µg and 10 µg.

Analysis of variance showed that the standing time was significantly different with all three doses studied. Further analysis by Turkey-Kramer Multiple Comparison Test showed that the standing time was significantly longer ($p < 0.05$) with 10 $\mu\text{g/kg}$ as compared to 5 $\mu\text{g/kg}$. There was no significant difference in the standing time with 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ of medetomidine.

Other observations

The observations of other clinical changes such as salivation, dropping head, lacrimation etc. in the 6 experimental animals are summarized in Table 7.

Table 7. Summary of changes observed in buffalo calves (Nos. 1-6) after administration of different doses of medetomidine.

Signs observed	Medetomidine 5 μg	Medetomidine 8 μg	Medetomidine 10 μg
Recumbency	1, 2 & 5	All	All
Salivation	All	All	All
Regurgitation	2 & 5	2, 4 & 5	1, 2, 4 & 6
Mild tympany	1, 2, 3 & 5	All	All
Lacrimation	1, 2 & 6	1 & 5	1, 2, 4, 5 & 6
Frequent urination	1, 3 & 4	3 & 4	1, 4 & 6
Defecation	4	No	No
Snoring	1 & 6	1, 4, 5 & 6	All
Bellowing	2, 3 & 5	1, 2, 4, 5 & 6	2, 3, 4 & 6
Head drooping	All	All	All
Rolling down of eye balls	1 & 6	1, 3, 4, 5 & 6	All
Presence of palpebral reflex	1, 3, 4 & 5	2, 3, 4, 5 & 6	3
Presence of pedal reflex	3, 4 & 5	None	None
Skin analgesia	1	All	All
Protrusion of the tongue	None	4 & 6	3 & 6
Drowsiness	All	All	All

Discussion

The onset of sedation was dose dependent was 185 s, 63.33 s and 40.83 s with 5 $\mu\text{g/kg}$, 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ of medetomidine respectively. Deep and rapid onset of sedation has been reported in dogs with 20 and 40 $\mu\text{g/kg}$ (i/m) of medetomidine (Clarke and England, 1989). Vainio *et al.*, (1989) reported that onset of sedation was within 1.5 min of administration of medetomidine in dogs. The duration of sedation was also dose dependent in buffalo calves after administration of medetomidine. Various workers have reported similar observations of dose dependent duration of sedation in dogs (Clarke and England, 1989; Vainio *et al.*, 1989) and rats (Tomizava, 1992). The onset of recumbency occurred within 4.33 min 3.33 min and 2.50 min with 5 $\mu\text{g/kg}$, 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ of medetomidine respectively. The onset of recumbency has been reported within 10 minutes at dose of 15 $\mu\text{g/kg}$ and 20 $\mu\text{g/kg}$ in goats (Muhammad *et al.*, 1989), in dogs within 0.6 min (Vainio *et al.*, 1989), in sheep at 17.1 min (Mohammad *et al.*, 1993) and in ail ferrets at dose of 8 $\mu\text{g/kg}$ of medetomidine (Ko and Jones, 1996). Duration of recumbency was 29.33 min, 50.17 min and 73.5 min with 5 $\mu\text{g/kg}$, 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ of medetomidine respectively. The duration of recumbency has been reported different with various doses and species Muhammad, *et al.*, (1989) observed that the duration of recumbency in goats was 1-1.5 hrs with 15 and 20 $\mu\text{g/kg}$ of medetomidine, Mohammad, *et al.*, (1993) reported the duration of recumbency in sheep as 58.1 min with dose rate of 40 $\mu\text{g/kg}$ and Ko and Jones (1996) noted the duration of recumbency in ferrets to be 100 minutes, 53.5 min and 76 min after administration of 5 $\mu\text{g/kg}$, 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ of medetomidine respectively. Muhammad, *et al.*, (1989) reported the standing time in goats as 1.5-2 hrs with 15 and 20 $\mu\text{g/kg}$ of medetomidine.

Medetomidine produced other side effects such as ataxia and muscle relaxation in buffalo calves with all three doses studied. The results are in agreement with such observations by Muhammad, *et al.*, (1939) in goats with 15 and 20 µg/kg of medetomidine. Ruminal stasis was noted in buffalo calves after use of medetomidine. Similar results have also been reported in goats (Muhammad, *et al.*, 1989) and in sheep (Muhammad *et al.*, 1993).

Medetomidine is potent CNS depressant in buffalo calves. A dose rate of 5 µg/kg of medetomidine produces light sedation, which facilitates easy handling of animals. This dose rate may also be used for pre-anaesthetic medication. Higher doses (8 µg/kg and 10 µg/kg) produce immediate sedation in buffalo calves with animals becoming drowsy and standing quietly with it's drooping head lowered beyond knees. Animals eventually go into voluntary recumbency within few minutes. Higher doses also produce good skin analgesia and some muscle relaxation. Medetomidine at the dose rate of 8 µg/kg produces moderate sedation which may be useful for performing diagnostic procedures as well as for minor procedures such as dressing of wounds, removal of sutures, opening of abscess, application of plaster casts, passing of urinary catheter, radiography etc. The dose rate of 10 µg/kg of medetomidine produces deep sedation, which may be employed along with local/regional anesthesia for performing minor surgeries such as tail docking, dehorning, castration etc.

Side effects such as salivation, regurgitation, mild tympany, lacrimation, snoring, bellowing and drowsiness do not appear to cause much alarm except for salivation and regurgitation which need special attention. Saliva may enter the respiratory tract in recumbent animals and cause suffocation. This can be prevented by giving an injection of atropine sulphate. Saliva or regurgitation may cause asphyxiation, hence lowering of the head is important to allow the free flow of saliva or regurgitated contents from the mouth.

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PHYSIOLOGICAL EFFECTS OF MEDETOMIDINE IN BUFFALO CALVES

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Abstract: Physiological changes produced by three doses of medetomidine hydrochloride (5µg/kg; 6µg/kg and 10µg/kg) were studied in six healthy buffalo calves. Pulse and respiratory rates decreased after intravenous administration of medetomidine. Maximum decrease occurred at 10 to 15 minutes. There were little changes in body temperature. Medetomidine produced a dose dependent significant increase in the serum glucose level. The maximum increase occurred at 30 minutes with all three doses.

Keywords: Buffalo, medetomidine, hydrochloride, physiological responses

Introduction

Pakistan is an agriculture country, where livestock plays an important role by contributing 30 per cent of the total income from agriculture. Buffalo has an important place in the rural economy of Pakistan. Pakistan has 9 per cent (18.3 million) of the world buffalo population and is a big buffalo milk producer, which is equivalent to 29 per cent of the world buffalo milk production. At the national level, buffalo contributes over 74 per cent of milk produced by the country. The buffaloes of Pakistan are of the riverine type and comprise two buffalo breeds (Kundhi and Nili Ravi) which are ranked as the finest breeds in the world. The milk yield of Kundhi buffaloes varies from 1700 to 2200 liters per lactation. However, the Kundhi breed has the potential to produce 4000 to 5000 liters of milk. Pakistan is also the world's largest buffalo meat producer.

Various diseases affect the health of animals with consequent effects on production. Therefore, treatment of diseases is essential for maintenance of high standards of animal health and its by-products. Recent advances in the discovery of new anaesthetics, sedatives and surgical equipment have enabled diagnosis and treatment of a number of diseases in ruminants to be carried out rather conveniently which otherwise would have been impossible in the past.

Medetomidine 4-[1-(2, 3, dimethyl phenyl) ethyl]-1 H-imidazole monohydrochloride is a very potent and selective alpha-2 adrenergic agonist. It is a mixture of two optical isomers, the dextrorotatory isomer being the active component and is used as a sedative, hypnotic, analgesic and premedicant (Hall and Clarke, 1991).

Before its introduction into the US market, medetomidine had acquired extensive development and clinical history in Europe since 1989. Approximately three million doses have been used in Europe, where product safety and efficacy have been well established (Anon, 1996).

The pharmacological restraint and pain relief provided by medetomidine facilitates handling of animals and aids in the conduct of diagnostic or therapeutic procedures. Medetomidine also facilitates the restraint of animals during minor surgical procedures (with or without local anaesthetic) and dental care where intubation is not required. The objective of this study was to examine the physiological responses to three doses of medetomidine hydrochloride.

Materials and Methods

Animals

A total of six healthy male Kundhi buffalo calves aged between 6 to 10 months and weighing 80 to 100 kg were used in this study (Table 1). All animals were clinical healthy and were purchased from a local market. The animals were housed in loose boxes and allowed a minimum period of two weeks for adaptation. Calves were given physical exercise and left in the open for grazing in the morning and evening. Before the experiment the calves were vaccinated against Haemorrhagic septicaemia and dewormed. The calves were fed on lucerne chaff. Feed was withheld for 12 to 15 hours before start of the experiments. Water was available *ad libitum*.

Table 1. Age and body weight of buffalo calves

Animal No	Age (months)	Weight (kg)
1	6	100
2	8	90
3	7.5	85
4	10	80
5	7	95
6	6	88

Experimental design

Three different doses of medetomidine hydrochloride (Domitor^R, Orion Corporation, Orion-Farmos, Espoo, Finland) were used in a crossover manner as described in the Table 2. Each animal received all 3 doses in rotation with an interval of at least 7 days between the two doses. Medetomidine was rapidly administered intravenously into the right or left jugular vein through an indwelling intravenous cannula. For precise dosage, a 1 ml disposal syringe was used. The dosage was calculated on body weight. The animals were subjected to a thorough clinical examination and only those animals found to be healthy were used in the study.

Table 2. Experimental design

Animal No	Doses of medetomidine		
	1 st week	2 nd week	3 rd week
1	A	B	C
2	B	C	A
3	C	A	B
4	A	B	C
5	B	C	A
6	C	A	B

A = 5 µg/kg; B = 8 µg/kg; C = 10 µg/kg

Results

Pulse rate

The baseline pulse rates were 58.5, 61.3 and 62.0 per minute with 5 µg/kg, 8 µg/kg and 10 µg/kg, respectively. These values were not significantly different from each other (Table 3). The pulse rate decreased after administration of medetomidine and this decrease was dose dependent. The maximum decrease in the pulse rate occurred 15 minutes after administration of medetomidine. The pulse rate then started to gradually return towards the base line. However, with the 10 µg/kg dose rate, the pulse rate was still significantly below the control at 90 minutes after administration of medetomidine, which was the last time point recorded on the day of experiment. The decrease in pulse rate was not statistically significant with the dose rate of 5 µg/kg, but was highly

significant ($p < 0.01$) up to 30 minutes, 50 minutes and significant ($p < 0.05$) up to 85 and 90 minutes, with 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ respectively. The mean values at 40 and 60 minutes were significantly lower ($p < 0.05$) with 10 $\mu\text{g/kg}$ as compared to corresponding values with 5 $\mu\text{g/kg}$.

Table 3. Mean pulse rates (per minute) of buffalo calves after administration of different doses of medetomidine

Time Minutes	Medetomidine (5 μg)		Medetomidine (8 μg)		Medetomidine (10 μg)	
	Mean	S. Error	Mean	S. Error	Mean	S. Error
Control	58.5	3.344	61.333	3.412	62.00	2.828
5	52.00	2.53	41.167**	4.339	43.667**	3.947
10	50.333	2.848	40.500**	3.344	40.00**	3.141
15	48.667	2.348	39.667**	2.616	39.00**	3.416
20	49.333	2.044	42.50**	3.096	40.333**	4.145
25	52.00	1.932	44.00*	2.921	44.00*	5.292
30	53.333	3.169	42.667**	2.290	39.833**	3.936
35	53.333	3.252	46.333	3.323	42.00**	4.782
40	56.333 π	2.445	46.167*	2.994	42.50** π	3.948
45	55.333	2.565	45.333*	3.040	43.833**	4.246
50	57.00	1.693	46.333*	2.155	45.667**	3.667
55	57.00	2.352	50.667	3.712	46.833*	3.331
60	60.00 π	2.251	51.50	3.384	45.167** π	3.038
65	59.333	3.040	48.00*	2.251	47.333*	2.906
70	57.333	2.404	48.667*	1.687	48.333*	2.753
75	56.00	2.582	49.667	2.753	47.00*	2.671
80	55.00	2.352	48.667*	2.108	48.00*	2.00
85	57.00	2.517	47.667*	1.498	48.00**	1.770
90	58.00	2.422	49.333	2.231	48.333*	2.539

* = Significantly different at ($P < 0.05$ level) from baseline value

** = Significantly different at ($P < 0.01$ level) from baseline value

π = Significant different at ($P < 0.05$ level) between values of 5 μg and 10 μg

Respiratory rate

The baseline values for respiratory rate were 32.3, 31.3 and 25.3 per minute with 5 $\mu\text{g/kg}$, 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$, respectively. These values were not statistically significant from each other (Table 4). There was significant decrease in respiratory rate after administration of medetomidine. The maximum decrease in respiratory rate occurred at 15 minutes with 5 $\mu\text{g/kg}$ and 8 $\mu\text{g/kg}$ and at 10 minutes with 10 $\mu\text{g/kg}$ of medetomidine. The respiratory rate then started to gradually return towards the base line. The decrease in respiratory rate was highly significant ($p < 0.01$) up to 20 minutes, 50 minutes and 45 minutes and significant ($p < 0.05$) up to 30 minutes, 65 minutes and 50 minutes with 5 $\mu\text{g/kg}$, 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ of medetomidine respectively. The mean values at 30 minutes were significantly lower ($p < 0.05$) with 8 $\mu\text{g/kg}$ as compared to corresponding values with 5 $\mu\text{g/kg}$ of medetomidine. Similarly mean values at 40 and 45 minutes were significantly lower ($p < 0.05$) with 10 $\mu\text{g/kg}$ as compared to corresponding values with 5 $\mu\text{g/kg}$ of medetomidine.

Body temperature

The baseline values for body temperature were 99.96 $^{\circ}\text{F}$, 100.90 $^{\circ}\text{F}$ and 100.07 $^{\circ}\text{F}$ with 5 $\mu\text{g/kg}$, 8 $\mu\text{g/kg}$ and 10 $\mu\text{g/kg}$ respectively (Table 5). There were little changes in body temperature after administration of medetomidine. Statistical analysis showed that there was no significant difference between the three doses as well as between control and post-medetomidine values.

Table 4. Mean respiratory rates (per minute) of buffalo calves after administration of different doses of medetomidine

Time Minutes	Medetomidine (5 µg)		Medetomidine (8 µg)		Medetomidine (10 µg)	
	Mean	S. Error	Mean	S. Error	Mean	S. Error
Control	32.333	3.552	31.333	3.169	25.333	1.520
5	16.00*	4.435	8.667**	0.667	8.167**	1.276
10	16.333**	4.507	7.000**	0.258	7.833**	1.014
15	15.167**	4.393	6.833**	0.477	8.000**	0.816
20	15.333**	3.648	7.667**	0.667	8.167**	1.014
25	19.50*	5.714	7.000**	0.730	8.167**	1.108
30	19.167**	5.218	7.000**	0.894	8.333**	0.954
35	21.333	4.759	12.500**	4.724	8.333**	1.202
40	22.333 ^π	4.522	12.167**	3.591	7.867** ^π	1.054
45	22.167 ^π	4.983	12.667**	4.022	7.333** ^π	0.954
50	22.50	4.992	13.500**	4.731	8.867*	0.422
55	23.333	2.552	13.833*	5.642	14.667	3.127
60	26.833	5.089	14.833	6.640	14.500	2.872
65	25.667	5.426	14.167*	5.576	14.667	3.303
70	28.667	4.971	15.667	5.731	15.167	3.825
75	28.833	5.009	20.000	6.191	15.00	4.228
80	29.00	4.698	19.167	6.112	16.667	4.341
85	30.50	3.739	19.667	5.937	19.333	3.827
90	31.00	2.955	21.000	5.922	21.833	4.438

* = Significantly different at (P<0.05 level) from baseline value

** = Significantly different at (P<0.01 level) from baseline value

^π = Significant different at (P<0.05 level) between values of 5 µg and 10 µg

+ = Significant different at (P<0.05 level) between values of 5 µg and 8 µg

Serum glucose

The mean control values for serum glucose were 59.61 mg/dl and 71.73 mg/dl with 5 µg/kg, 8 µg/kg and 10 µg/kg respectively. These values were not significantly different from each other (Table 6). There was significant increase in serum glucose level after administration of medetomidine and this increase was dose dependent. Maximum increase in serum glucose level occurred at 30 minutes with all three doses of medetomidine. The serum glucose level then started to gradually return towards the base line. Serum glucose analysis at 90 minutes showed that by then it had returned to the base line in all three doses (as statistical analysis showed no significant difference between control values and those at 90 minutes). The mean values for serum glucose level were significantly lower at 5 minutes (p<0.05), 30 minutes (p<0.01) and 90 minutes (p<0.05) with 5 µg/kg as compared to corresponding values with 10 µg/kg of medetomidine. Similarly, mean values at 60 and 90 minutes were significantly lower (p<0.05) with 8 µg/kg as compared to corresponding value with 10 µg/kg of medetomidine.

Discussion

The pulse rate of buffalo calves decreased after administration of 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine with a maximum decrease at 15 minutes with all three doses. The results revealed that there was a dose dependent effect of medetomidine on pulse rate. Decrease in pulse rate has also been reported by other workers when medetomidine was used in dogs (Clarke and England, 1989), sheep (Mohammad *et al.*, 1993) and goats (Muhammad *et al.*, 1989). The respiratory rate decreased significantly with 5 µg/kg, 8 µg/kg and 10 µg/kg of medetomidine. Other workers have also reported depression of respiratory rate when medetomidine was used in dogs (Clarke and England, 1989), goats (Muhammad *et al.*, 1989), sheep (Muhammad *et al.*, 1993) and rats (Tomizawa *et al.*, 1992).

Table 5. Mean body temperature ($^{\circ}\text{F}$) of buffalo calves after administration of different doses of medetomidine.

Time	Medetomidine (5 μg)		Medetomidine (8 μg)		Medetomidine (10 μg)	
	Mean	S. Error	Mean	S. Error	Mean	S. Error
Control	99.967	0.668	100.90	0.313	100.07	0.424
5	100.05	0.661	100.97	0.1745	100.37	0.370
30	99.783	0.562	100.97	0.298	100.10	0.389
60	99.900	0.558	100.67	0.217	99.367	0.377
90	99.750	0.619	100.50	0.321	99.383	0.350

Table 6. Mean serum glucose (mg/dl) of buffalo calves after administration of different doses of medetomidine.

Time	Medetomidine (5 μg)		Medetomidine (8 μg)		Medetomidine (10 μg)	
	Mean	S. Error	Mean	S. Error	Mean	S. Error
Control	59.617	1.736	58.650	2.999	71.733	5.835
5	73.100 [*]	2.805	76.233	6.284	96.067 ^{*π}	7.875
30	88.917 ^{**$\pi\pi$}	2.799	100.62 ^{**}	3.357	113.97 ^{**$\pi\pi$}	6.005
60	82.533 [*]	5.231	80.376 ^{*Δ}	4.183	101.33 ^{**Δ}	4.919
90	66.900 [*]	2.946	68.28 ^{Δ}	4.887	87.550 ^{Δ}	4.610

* = Significantly different at ($P < 0.05$ level) from baseline value

** = Significantly different at ($P < 0.01$ level) from baseline value

π = Significant different at ($P < 0.05$ level) between values of 5 μg and 10 μg

$\pi\pi$ = Significant different at ($P < 0.01$ level) between values of 5 μg and 10 μg

Δ = Significant different at ($P < 0.05$ level) between values of 8 μg and 10 μg

This study revealed a significant effect of medetomidine on serum glucose on buffalo calves. The results show a significant increase in serum glucose. This finding is in agreement with findings of others (Muhammad *et al.*, 1989), who used medetomidine in goats. The body temperature slightly changed after administration of medetomidine. However, other workers have reported that medetomidine causes hypothermia in dogs (Clarke and England, 1989) and in goats. No such change was noted in buffalo calves in this study. Medetomidine produces a number of side effects. Decrease in pulse and respiratory rates and an increase serum glucose levels have been recorded in all buffalo calves used in the present study. These changes may not be important in healthy animals but care must be taken in patients with hypovolaemia and with respiratory and renal insufficiencies.

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SYMPOSIUM - IV

Health

Discussion

Q. D.K. Seneviratne - A disease syndrome has been encountered in the field, where a large number of calves were dying of diarrhoea. Do we have tests to identify viral diarrhoea?

A. N.P. Sunil Chandra - The spread of infection should be prevented by isolating diarrhoeic animals. There could be a number of causes for diarrhoea, e.g. bacterial or viral. Among bacterial infections, *E. coli* may be involved. In the case of viral infections, rota virus can be suspected and diagnostic tests should be directed to identify the causative agent. A sample of stools should be examined. Florescent antibody test (FAT) can be employed to detect rota viral diarrhoea. Diagnostic kits are also available. In order to control the spread of infection, hygienic measures should be adopted.

Q. N.P. Sunil Chandra - Is there any change in the multiplication of the bacteria?

A. N.U. Horadagoda - By inoculating endotoxin of *Pasteurella multocida* many pathological lesions were produced which can be considered as a virulence factor.

Q. D.H.A. Subasinghe - What is the level of infection/disease that could be elicited by this method?

A. N.U. Horadagoda - It appears that there is a dose relationship between the endotoxin and the disease.

Q. N.P. Sunil Chandra - The experimental methods used by you to activate the carrier status may not be the ideal. Did you confirm the establishment of "latent carrier" status in the experimental animals?

A. P. Abeynayake - We tried to simulate the natural stress condition. However, it may have been better if we had performed an autopsy and isolated the organisms.

Q. D.H.A. Subasinghe - Prior to the establishment of carrier state in the experimental animals through artificial means, would it not be possible for them to have had a latent infection, detectable perhaps by an HA or by more sensitive immunological or other techniques?

A. Thula Wijewardena - The absence of the carrier status in the experimental animals was established by serological studies conducted on them prior to the commencement of the experiment.

Q. D.H.A. Subasinghe - I believe that there could be a host of factors responsible for causing a latent carrier to spontaneously shed the pathogenic organisms initiating an outbreak of disease as observed particularly under field conditions. What would be your comments?

A. P. Abeynayake - Yes. A multitude of factors could come into to play, for the commencement of an outbreak under field conditions.

THE APPLICATION OF BIOTECHNOLOGY IN IMPROVING THE PRODUCTIVITY OF THE BUFFALO

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Abstract: The buffalo, mankind's most valuable animal genetic resource, is predominantly an Asian animal with small populations scattered in some 40 countries in other continents. Of the global population of 150 million buffaloes, 133 million (97%) are in Asia and the Pacific, contributing significantly to its rural economy through milk, meat, draft and hide. More than 60% of the annual milk production has made the buffalo the backbone of the dairy industry in India, and the largest producing country in the world. Thus, the onus of developing this wonderful animal lies with these countries.

In the last two decades, research interest in the buffalo has grown and the application of biotechnology is considered necessary for improving the productivity of the buffalo. The first generation biotechnology includes oestrus detection, oestrous synchronisation and artificial insemination. In fact, artificial insemination and frozen semen technology has been the greatest inventions of the animal scientists in the last century, which has transformed animal productivity, especially in cattle. Although the first artificially bred calf was produced in India in 1943, subsequent efforts in field use have not been very successful because of poor coverage of the breedable population, poor selection of breeding bulls and poor technical skills at the grass root level. The second generation biotechnology includes embryo transfer and associated technologies such as *in vivo/in vitro* embryo production, embryo cryo-preservation, embryo transfer, embryo sexing and embryo micro manipulation, which are being used or improvised for use in the laboratory and in farm animals. Cloning (using embryonic, foetal and adult somatic cells), transgenics and embryonic stem cell technology have the potential to revolutionise buffalo productivity in future. This paper deals with an overview of the potential and prospects of application of biotechnology in improving the productivity of the buffalo.

Introduction

The buffalo, mankind's most valuable animal genetic resource, is predominantly an Asian animal. The global buffalo population is estimated to be about 150 million in some 40 countries, of which 133 million (97%) are in Asia and the Pacific. India alone has over half the population (about 78 million) and China has the second largest population (22 million) of buffaloes in the world. In most countries, buffalo numbers are increasing steadily.

Buffaloes contribute significantly to the rural economy through milk, meat, draft and hide. The contribution of about 60% of the annual milk production has made the buffalo the back bone of dairy industry in India, and the largest milk producing country of the world. This has happened, in spite of the fact that in any planned programme for improving animal productivity, the cow in preference to buffalo has enjoyed the monopoly of the organised sector and there has been a failure to realise that the buffalo complements and not competes with cattle. Additionally, lack of adequate infrastructural facilities in the past has also deterred the application of modern genetic and biotechnological methods in bringing about genetic improvement.

The buffalo has some inherent deficiencies such as delayed puberty, weak behavioural oestrus, poor conception, long post-partum anoestrus and inter-calving intervals and seasonality in breeding. The genetic improvement of these traits will enable buffaloes to hold their ground against the cattle. While planning the strategy for the genetic improvement, the change must be rapid and achievable in the shortest period of time. In the last two decades, research interest in

buffalo has grown and the application of biotechnology is considered necessary for improving the productivity of the buffalo.

There have been different generations of biotechnology in the improvement of the productivity of the buffalo. The first generation biotechnology includes oestrus detection, oestrus synchronization and artificial insemination. The second generation biotechnology includes embryo transfer, in *vitro* production of embryos (including ovum-pick-up, in *vitro* maturation, in *vitro* fertilization, in *vitro* culture/co-culture), embryo sexing etc. The emerging, third generation biotechnologies are cloning, transgenics, embryo stem cell technology etc.

Oestrus Detection, Oestrus Synchronisation and Artificial Insemination (AI)

Oestrus detection

Accurate detection of onset of oestrus is a challenge in buffaloes. Acceptance of the male is the most reliable sign of oestrus in the buffalo, however, less than a third of buffaloes in oestrus are detected by homosexual behaviour. Other clearly defined behavioural oestrus symptoms *viz.* swelling of the vulva, discharge of clear mucus from the vulva, increased frequency of micturition, restlessness, repeated vocalisation and a drop in milk production are not as prominent as in cattle. Low progesterone profile and lower oestradiol 17- β elevation at oestrus are primary causes of poor oestrus expression. Many buffaloes exhibit suboestrus or silent oestrus. Intensity and duration of oestrus varies from season to season. During summer, most of the buffaloes express oestrus during the coolest hours of the day (10.00 pm to 6.00 am). However, with improved management and by providing thermal amelioration to the housed animals, more buffaloes express detectable oestrus during summer.

Oestrus synchronization

Oestrus synchronisation facilitates oestrus detection and controlled timely breeding. As the luteal phase of the bubaline oestrous cycle is susceptible to external intervention, two basic techniques in use are:

1. Prolongation of the luteal phase of the oestrous cycle by exogenous progesterone or progestagens
2. Induction of luteolysis by exogenous prostaglandin $F_2\alpha$

A combination of the above two methods can also be used.

Use of progesterone/progestagen

Progesterone and synthetic progestagens have been successfully used to synchronize oestrus in the buffalo (Rao and Rao, 1979; Rao and Rao, 1983; Shankar, 1986; Bhosrekar *et al.*, 1994). Recent studies indicate that progestagens act via a mechanism of negative feed back on LH secretion, probably by reducing the LH pulse frequency. Common methods for administering progestagens for oestrus synchronisation are:

Intravaginal sponge pessaries: Sponges are generally impregnated with 3 gm of natural steroid or 200 mg of progestagen like FGA (Fluorogestone acetate). They are usually used over a short term period (9-10 days) with an oestrogen-progestagen injection given at the time of initiation of treatment.

Progesterone releasing intravaginal device (PRID): A metal spiral coated with progesterone impregnated silicone rubber is inserted in the vagina along with a gelatin capsule containing 10 mg oestradiol benzoate and retained for 12 days.

Subcutaneous implant: Syncro-Mate-B/Crestar, an ear implant containing 6 mg of an extremely potent progestagen (Norgestomate) is inserted along with an intramuscular injection of 3 mg Norgestomate and 5 mg oestradiol valerate at the time of implant insertion. The removal of implant after a 9 day period results in a satisfactory oestrus response (24-48 hrs after removal) and acceptable fertility.

The exogenous progesterone supply prolongs the luteal phase of the cycle. As long as the progesterone concentration is maintained high in the blood, the animal does not exhibit oestrus. With the withdrawal of the exogenous source of progesterone, the blood levels of progesterone drop down, mimicking the proestrus endocrinological conditions and buffaloes come into oestrus with reasonable synchrony.

Use of prostaglandin

When exogenous prostaglandin ($\text{PGF}_{2\alpha}$) is used in a buffalo with a susceptible CL (Day 6 to 17 of cycle), the plasma progesterone level rapidly declines to $< 1 \text{ ng/ml}$ within 24 hours. Oestrus is usually exhibited within 36 to 77 hours (Perera *et al.*, 1977; Rao and Rao, 1978; Shankar, 1986; Rajeshwaran *et al.*, 1992). A single injection of $\text{PGF}_{2\alpha}$ should result in oestrus in 50 to 65% of cycling animals. A second injection given 11 days later, results in synchronised oestrus in 90% of the animals. Synchronization of oestrus is found to be better after second $\text{PGF}_{2\alpha}$ injection than after the first. This may be because of synchronization of follicular development before the second injection.

Progestagen-prostaglandin combination: To synchronise oestrus in the animals not in the luteal phase (and hence non-susceptible to $\text{PGF}_{2\alpha}$), all the animals are put under progestagen treatment for a 7 day period (using IMPLANT/PRID). A luteolytic dose of $\text{PGF}_{2\alpha}$ is administered 24 h before or at the time of progestagen withdrawal. This combination avoids the need for oestrogen/progestagen doses at the start of progestagen treatment.

Artificial insemination (AI)

The AI technology enabled the organisation of genetic improvement in cattle in Europe and America during the 1960's and is considered to be the most outstanding and powerful tool in the hands of animal scientists for the genetic improvement of the livestock. The genetic gain through AI is achieved by full utilisation of a proven elite bull to produce hundreds of superior progenies. Therefore, the success of AI primarily depends upon the intensity and accuracy of selection exerted on the breeding bulls and coverage of large population through AI.

Although the first artificially bred AI buffalo calf was produced at the Agriculture Institute, Allahabad in 1943, subsequent efforts were not very successful because of poor coverage (only about 10%) of breedable (about 41 million) population, poor selection criteria adopted to select bulls for breeding purposes and the lack of adequate technical know-how at the grass root level, where this technique could effect a change in terms of production.

Progeny testing of the bull

Progeny testing (PT) is one of the selection indices used by animal geneticists to evaluate the genetic merit of bulls with regards to several traits, that are heritable to its progenies. In this selection method, bulls that are selected meticulously are allotted to a group/area covering the

female population through AI. The daughters born to different sires are evaluated for their traits inherited from their father, especially the production traits. These are then compared with their contemporaries for the genetic gain achieved within them and thus the bulls having a positive index are rated as progeny tested, which can be used to cover a large population.

The Indian Council of Agriculture and Research (ICAR) initiated the PT scheme in India as early as in 1973 at selected centres and under the All India Co-ordinated Research Project on buffaloes. Under this project the National Dairy Research Institute (NDRI), Central Institute for Research in Buffaloes (CIRB) and the Punjab Agricultural University (PAU) has progeny tested some buffalo bulls (Sethi, 1999). In Gujarat, the field progeny testing is being carried out by the National Dairy Development Board (NDDB) under the project "Dairy Herd Improvement Programme Action" (DIPA) to improve milk production in buffaloes at the grass root level. About 250 bulls have been subjected to testing so far and the proven Murrah and Mehsani semen is now available for use.

Cryopreservation of Sperm, Oocyte and Embryo

Cryopreservation of buffalo sperm is a routine practice, but freezing of buffalo embryos is a relatively new endeavour to preserve the germplasm for future use. Oocyte freezing is still in the process of standardisation to optimise efficient post-thaw survival.

Principles in cell and embryo cryopreservation

In the process of cryopreservation, metabolism of cells, tissues and embryos is reversibly arrested and they are kept in a state of suspended animation for indefinite period, without interfering with their viability. Nevertheless, two injurious factors experienced by cells during freezing are: i) solution effect, ii) intracellular ice formation. These adverse effects are counteracted by using a suitable concentration of cryoprotective agents (CPA) and proper rate of cooling. In general, injury associated with "solution effect" is more pronounced at slower cooling rate while intracellular ice formation is an outcome of higher cooling rate. Thus, movement of water across the cell membrane plays a key role and is governed by the nature and concentration of cryoprotective agents (CPA), duration of application, permeability of the cell membrane and rate of freezing/thawing. The commonly used CPA are classified as: a) permeating solutes of low molecular weight such as glycerol, dimethyl sulphoxide, glycols and alcohols and b) non-permeating solutes of low and high molecular weights such as sucrose, polyvinyl pyrrolidone, dextran, serum and bovine serum albumin. The use of CPA results in reduction in the amount of water that freezes as ice at sub-zero temperatures by organising neighbouring water molecules. There is a positive correlation between concentration of CPA and their cryoprotective activity, however the higher concentration of CPA is harmful to the membrane lipids and electrolyte transport.

Cryopreservation of buffalo sperm

Since the discovery of the cryoprotective properties of glycerol in 1949 (Polge *et al.*, 1949), the cryopreservation of spermatozoa has had a profound effect on livestock breeding. The methods developed for cryopreserving sperm in cattle have been found generally applicable to buffalo also. After the first successful attempt at freezing buffalo semen (Bhattacharya and Srivastava, 1955), it is now routinely frozen in India (Bhosrekar *et al.*, 1994; Misra *et al.*, 1994b) and several other buffalo rearing countries (Shabbir *et al.*, 1982; Vale, 1997).

Cryopreservation of buffalo oocyte

The ability to store mammalian oocytes at subambient temperatures for extended periods of time would establish oocyte banks to preserve pure genetic resources besides facilitating their use for research, as well as for commercial purposes. Attempts have been made to develop techniques for cryopreservation of bovine oocytes using conventional slow freezing and vitrification methods*

The primary problem with cryopreservation of oocytes is the low percentage that retain their ability to undergo normal maturation and fertilisation, primarily due to an increase in morphological abnormalities, a decrease in oocyte fertility and an increase in chromosomal abnormalities. Japanese workers have reported the production of normal offspring from oocytes frozen-thawed at the mature stage and fertilized *in vitro* (Fuku *et al.*, 1992 and Otoi *et al.*, 1996).

in vitrification of buffalo oocytes, cumulus oophorus complexes (COCs) are aspirated in a medium consisting of TCM-199 + 5% oestrus buffalo serum (EBS) and Dulbecco's phosphate buffered saline (DPBS) + 0.6% BSA at a 1:1 ratio (V/V). Vitrification medium consists of 3.5 to 4.5 M Ethylene glycol, 3.4 M Dimethyl sulphoxide, 5.36 mM Glucose, 0.33 mM Sodium pyruvate and 0.4% w/v BSA in DPBS. Equilibration solution is prepared by 50% dilution of the vitrification medium in DPBS. Prior to vitrification, the COCs are exposed to equilibration medium for 3 min at room temperature (25-30° C). Groups of 4 to 5 oocytes are then placed in vitrification medium and immediately loaded into 0.25 ml French straws containing 150 µl of 0.5 M Sucrose in DPBS. The straws are placed in liquid nitrogen vapour for 2 min and then plunged into liquid nitrogen.

Thawing

The straws are thawed in water at 28° C for 20 sec and the oocytes are equilibrated for 4 min in 0.5 M Sucrose in a one-step dilution, (Dhali *et al.*, 2000).

Vitrification of buffalo oocytes have been reported with subsequent 18.1 to 75.0% (Nag and Maurya, 1997; Saxena, and Maurya, 1999) and 24 to 33% (Dhali *et al.*, 2000) maturation rates. However, birth of buffalo calves following cryopreservation of buffalo oocytes has yet not been reported.

Cryopreservation of embryos

Like semen, buffalo embryos can be cryopreserved and stored in the embryo bank for future use. Methods used for the cryopreservation of embryos are:

Conventional cryopreservation

Glycerol (1.0/1.4 M) in holding media (DPBS + 0.4% BSA) is used as a cryoprotectant. Embryos selected are kept in freezing medium (holding medium +1.0/1.4M glycerol) for glycerolization for 20 min at room temperature (25°C). During this period embryos are loaded into the middle of a 0.25 ml (133 mm long) French straw, guarded by two air pockets. Only one embryo is packed in one straw, labelled for identification and sealed. Embryo freezing is carried out in a programmable biofreezer and embryos are cooled to -33°C in a controlled manner as per following protocol:

1. Cooling rate 4 °C per min from room temperature to 0 °C.
2. Straws loaded with embryos are transferred to freezer.
3. Cooling rate 1 °C/min from 0 °C to -7 °C.

4. Mold at -7°C for 5 min and seed the straws manually by touching with precooled (in liquid nitrogen) forceps at a location distant from embryo.
5. Hold again at -7°C for 5 min.
6. Cooling rate $0.4^{\circ}\text{C}/\text{min}$ from -7°C to -33°C .
7. Plunge straws into liquid nitrogen (-196°C).

Thawing and removal of cryoprotectant: Embryos are thawed by direct transfer of frozen straws from liquid nitrogen to a water bath maintained at 37°C for 30 sec. Cryoprotectant is removed using sucrose in a concentration of lower molarity than the glycerol in following three steps.

Step 1: 0.95 M glycerol plus 0.33 M sucrose in holding medium.

Step 2: 0.47 M glycerol plus 0.33 M sucrose in holding medium.

Step 3: 0.33 M sucrose in holding medium,

In each step, the embryos are allowed to remain in contact with the dilution medium for 5 min. The embryos are then transferred into holding medium and assessed for survival and quality. Thereafter, they are loaded into the straw for transfer into recipients.

Buffalo embryos have been successfully cryopreserved (Misra *et al.*, 1990; Misra *et al.*, 1992) and calves have been produced from frozen embryos (Kasiraj *et al.*, 1993). Our group had frozen over 730 buffalo embryos and about 150 frozen buffalo embryos are still available with the National Dairy Development Board. Use of such buffalo embryos under field conditions (at State ET Centre) have given up to 51.02% (25/49) pregnancy and 46.93% (23/49) calving rates (Singh *et al.*, 1999).

Technology of direct transfer of frozen-thawed buffalo embryos and vitrification of buffalo embryos to produce calves, which has been successfully used in cattle, needs to be developed. Methods for the direct transfer of frozen-thawed cattle embryos and vitrification are given below:

Direct transfer of frozen-thawed embryos

The ability to transfer frozen embryos directly to recipient females after thawing would be a convenience in the application of embryo transfer technology. This would also help in:

- Reducing the time required for the conventional step-wise thawing of frozen embryos and makes the transfer procedure easier.
- Using the recipients which are available for a limited amount of time each day since the direct transfer would be a quicker process.
- Better use of the recipients without disrupting the herd management.
- Eliminating the need for trained embryologists to be present during embryo transfer.
- Eliminating laboratory facility during the embryo transfer, since the embryos are not handled outside the straw.

Freezing of embryos: Bovine embryos (day 7.0 to 7.5) are equilibrated in 1.5 M ethylene glycol (EG) for 20 minutes. They are packed in 0.25 ml straws containing a central column of 3.5 M EG with the embryo and a column at each end of the straw containing holding medium. A ratio of 1 part EG to 3 parts holding medium is maintained in each straw and the straws are sealed. Embryo freezing is carried out in a programmable biofreezer and embryos are cooled to -35°C as per following protocol:

- Straws are placed into a programmable freezer at -7.0°C .
- Hold at -7°C for 5 min and seeded.
- Hold again at -7°C for 5 min.
- Further cooling at $0.5^{\circ}\text{C}/\text{min}$ from -7°C to -35°C .

- After 15 minutes at -35°C embryos are plunged into liquid nitrogen (-196°C)

Transfer: After thawing at 30°C in a water bath, the embryos are directly transferred into recipients.

The pregnancy rates for the embryos frozen and transferred directly to recipients was 50%, which is comparable to the pregnancy rate of embryos frozen in glycerol and rehydrated using a step-wise procedure for transfer (Voelkel and Hu., 1992).

Vitrification of embryos

Deep freezing and transport of embryos is now well established and commonly employed in cattle and buffalo. In conventional freezing, embryos are dehydrated by slow cooling to -30°C to -60°C in the presence of molar concentrations of cryoprotective additive and warming is carried out in a water bath at 37°C . This approach is classical one. But there is now a new promising approach called vitrification.

Vitrification is the solidification of a liquid brought about by an extreme elevation in the viscosity during cooling so that the solution is said to become a glass. This requires the presence of high concentrations of a cryoprotective agent (nontoxic to the embryos), high cooling and warming rates that both intracellular and extracellular compartments be vitrified simultaneously in order to successfully vitrify embryos.

Freezing: The embryos are exposed for 10 min in a mixture of 10% glycerol and 20% 1,2 propanediol in PBS. After a 10-min equilibration period at room temperature, embryos are aspirated at the tip of a pipette filled with the extracellular vitrification medium (25% glycerol + 25% 1,2 propanediol in PBS) and placed in a column (5mm long) of the same medium, located into a transparent 0.25 ml French straw. This column is separated by two air bubbles, from the diluent (IM sucrose in PBS solution) on each side. Immediately after loading, the straws are plunged directly but progressively in liquid nitrogen (Massip *et al.*, 1987). Others have used 25% ethylene glycol, 20% w/v PVP and 20% w/v sucrose in PBS as the vitrification medium (Hamawaki *et al.*, 1999).

Warming and dilution of cryoprotectant: Warming is done by immersion of the straw in a water bath at 20°C until ice has disappeared in the diluting medium. Soon after warming, the content of each straw is expelled into an embryological glass cup and left for 10 min. Thereafter, the embryo is pipetted one to three times in holding medium. With this approach fifteen frozen thawed cattle embryos gave 46.7% pregnancy (Massip *et al.*, 1987).

Embryo Transfer Technology (ETT)

Buffaloes have low reproductive ability, which limits the extent of increasing the selection intensity and the effective utilisation of genetically superior females in the population. This in turn reduces the rate of genetic progress of these animals. However, it is possible to overcome this limitation by using the embryo transfer technology. In ETT, an elite buffalo which excels over its contemporaries with regards to the productive genetic traits is considered as the donor animal, which is then superovulated using gonadotrophin hormone to induce multiple ovulations. Genetically superior bull (progeny tested) semen is used for inseminating the donor. The donor is flushed on day 5.5 - 6 of oestrus, to collect the embryos. The embryos are transferred into the synchronised recipients of no genetic importance. The experiments carried out and the up-to-date practices show that by applying ETT, it is possible for one donor to produce annually 10 - 15 calves, and at times even more.

Embryo transfer technology has a number of advantages and its use could contribute to increase the genetic potential of the buffalo population as follows:

Rapid proliferation of the elite female breeding stock

The low fecundity of the buffaloes can be overcome by the use of superovulation and transplantation of embryos to produce an increased number of progeny calves per donor.

Production of elite breeding bulls

Available stock of AI bulls is not only insufficient but is also mostly of substandard quality. With the buffalo, there is no scope for importing semen from bulls of superior genetic merit from any other country, as India has the best milch breeds. Accordingly, production of high pedigreed bulls are essential for the normal national AI programme. At the natural rate of reproduction, it does not seem feasible to meet the requirement of bulls from the elite female stock. Hence application of ETT is the only logical solution.

Sire evaluation through sibling testing

Routine ET techniques can be applied to produce bulls, which can be evaluated on the performance of their siblings (and half) in a very short period of time. An alternative strategy is to use MOET to distribute the progeny of selected matings more widely across the national herd and to select teams of young bulls for AI records of their full and half sisters, under the Open Nucleus Breeding System. In this way, the average genetic superiority of the bull is exploited more rapidly than conventional progeny testing. This MOET scheme operating from centralised farms may be particularly useful in developing countries like India, which lack the widespread recording systems.

Conservation and preservation of the endangered breeds

It is now emerging that some of the native breeds of buffaloes are declining rapidly and this may cause their eventual extinction. ET offers scope for the rapid multiplication of the population of these breeds of buffaloes.

Economic transport of livestock

Compared to live animals, hundreds of cryopreserved embryos can be transported globally in a small cryo can involving very little cost. Also, when these exotic embryos are used for the production of calves using native recipients, the calves gradually adapt to the local environment and are more resistant to diseases.

Future application through research

The economical production of large numbers of high quality embryos is a well defined goal of a commercial embryo transfer programme. However, the unpredictable and unreliable supply of embryos on a regular basis is the major limitation of such programmes. Recent advances to produce embryos *in vitro* have helped in overcoming this limitation, to some extent. Also, technological advances in understanding male/female gamete, fertilization, embryo and their manipulation has been phenomenal and has led to the development of, so called, embryo transfer associated technologies e.g. *in vitro* maturation, *in vitro* fertilization, *in vitro* culture, embryo sexing, embryo cloning, gene transfer etc. These technologies not only spur the impact of embryo transfer technology but are extremely powerful for scientific, commercial, medical, social and conservation purposes.

Salvage of reproductive function

Infertility, especially in the older animals is a major handicap in animal breeding. Such animals of superior genetic makeup could still be tapped through ET to provide additional progenies. Wastage of good genetic material can be prevented by utilizing germ plasma from slaughtered animals.

Embryos can be produced either *in vivo* or *in vitro*

In vivo production of embryos

Following steps are involved in the production of embryos *in vivo*.

Selection of animals.

Donors: Essentially, genetically superior animals preferably with one lactation record, having normal genitalia, patent cervix, regular cycle, true to breed characters, healthy and free from all major diseases.

Recipients: Low milk producers but high fertility females, with patent cervix, regular cycle, healthy and free from all major diseases.

Superovulation and artificial insemination

Superovulation is induced by Injecting gonadotrophins, mainly FSH or eCG between days 8 to 12 of the oestrous cycle. Because of its short biological half-life, FSH is injected twice daily over a period of 4 to 5 days whereas eCG with a long half-life is injected as single dose treatment. Luteolysis is induced by administration of PGF_{2α} at 72 and 84 h after the beginning of gonadotrophin treatment. Donors are inseminated 2 to 3 times during superoestrus, with frozen-thawed semen from fertile bulls.

Nonsurgical collection of embryos

The uterine horns of the superovulated donor are flushed on day 5.5 to 6 (oestrus = day 0) using the Dulbecco's modified Phosphate Buffered Saline (DPBS) solution containing antibiotics and serum, using a 2-way Rusch catheter. The outflow is passed through an embryo filter (pore size 75 micron) retaining only about 20ml volume and the same is passed into the laboratory for screening. Embryos are isolated and viable embryos are graded based on morphological appearance. Excellent and good quality embryos are selected for cryopreservation, whereas fair and poor quality embryos are immediately transferred to the synchronized recipients.

A considerable amount of progress was made in this field in buffaloes, after the birth of the first calf in 1983 at Florida (Drost *et al.*, 1983). In India the first buffalo calf through surgical and non surgical transfers was produced at Sabarnati Ashram Gaushala in 1988 (Misra *et al.*, 1988) and since then NDDB (SAG/BBC) has done pioneering work in ETT in buffaloes (Misra *et al.*, 1990; Misra *et al.*, 1991a; Misra *et al.*, 1991b; Misra *et al.*, 1992; Misra, 1993; Kasiraj *et al.*, 1993; Misra *et al.*, 1994a; Misra *et al.*, 1994c; Rao *et al.*, 1994; Misra, 1996; Misra *et al.*, 1998; Misra *et al.*, 1999a; Misra *et al.*, 1999b; Misra *et al.*, 1999c; Misra *et al.*, 2000). We have produced over 120 buffalo calves using ET technology.

During the implementation of the National Science and Technology Project on ET (1987-96) in the NDDB's network alone, a sizeable number of embryo collections were made from Murrah, Surti, and Jaffrabadi breeds. The progress is given below:

No.	Particulars	1987-92	1993-96	Field trials in Punjab			
				Ludhiana	Bhatinda	Patiala	Total
1	Animals flushed	719	316	10	25	10	45
2	Viable Embryos (mean)	804 (1.12)	635 (2.01)	15 (1.50)	56 (2.24)	59 (5.90)	130 (2.89)
3	Embryos frozen	315	351	0	32	34	66
4	Embryos transferred (fresh and frozen)	604	374	15	24	25	64
5.	Calves born (%)	37 (6.1)	67 (17.9)	5 (33.3)	7 (29.2)	5 (20.0)	17 (26.6)

A review of the embryo transfer work performed in different countries reveal that the superovulatory response and embryo recovery in buffalo has been very disappointing (Table 1). Over the years, efficiency in terms of embryo recovery has improved and now, on an average about 2.5 to 3.0 viable embryos are recovered from each superovulation. However in isolated cases, up to a mean of 5.9 (Misra *et al.*, 1999c), 3.6 (Wang *et al.*, 1994) viable embryos and 51.02% conception rates (Singh *et al.*, 1999) have been achieved.

Table 1. Review of superovulation and embryo collection in buffalo

Country	Breed	Gonado trophin	Donors superov ulated	Donors flushed	Total CL or (mean)	Total embryo or (mean)	Viable embryo or (mean)	Reference
USA	Riverine	FSH	1	1	2	1	1	Drost <i>et al.</i> , (1983)
USA	Riverine	FSH	26	19		18	1	Drost and Cripe, (1985)
Bulgaria	Riverine	FSH/ PMSG	19 54	-		35	2	Vlahov <i>et al.</i> , (1985)
Bulgaria	Murrah & Murrah X	FSH/ PMSG	71	45 26 (SLT)		66 28		Karalvanov, <i>et al.</i> , (1987)
Bulgaria	Murrah & Medit	FSH	34	24	(4.0)	(1.2)	(1.17)	Drost <i>et al.</i> , (1988)
Bulgaria	Murrah & Murrah X	FSH/ PMSG	126 75	123 66	(4.0) (3.4)	46(1.2) 54(0.7)	132 38	Alexiev <i>et al.</i> (1988)
Thailand	Swamp	FSH/ PMSG	7 5	7 5	26 15	10 6	6	Chantaraprateep <i>et al.</i> , (1988)
Japar	Murrah & Swamp	PMSG	4	3	9	2	0	Ocampo <i>et al.</i> , (1988)
Pakistan	Nili-ravi	FSH	12	2	(3.7)	(0.5)	-	Rahil <i>et al.</i> , (1988)
Malaysia	Swamp	FSH /PMSG	17 32	54	(3.6) (4.3)1-			Sharifuddin and Jainudeen, (1984)
India	Murrah	FSH	73	69	(3.7)	(2.7)	(1.5)	Misra <i>et al.</i> , (1990)
Italy	Medit.	PMSG	10	6	27	16		Schallenger <i>et al.</i> , (1990)
India	Murrah	FSH	16	16	(6.8)	(4.4)	(3.1)	Misra <i>et al.</i> , (1991)

India	Murrah	FSH	22	22	82	52	30	Ambrose <i>et al.</i> , (1991)
Philippines	Murrah	FSH/ PMSG	7 4	7 4	20 6	14 0	4 0	Cruz <i>et al</i> (1991)
India	Murrah	FSH /PMSG	115 10	70 10	249 31	60 0	33 0	Jain <i>et al</i> (1992)
Vietnam	Swamp	FSH	15	15	90?	-	-	Uoc <i>et al.</i> , (1992)
Pakistan	Nili-ravi	FSH	20	20	75	35	22	Ullah <i>et al.</i> , (1992)
India	Murrah	FSH/ PMSG	356	497	-	1,302	712	Misra <i>et al.</i> , (1994)
India	Murrah	FSH	41 [†] 158*	41 154	(8.2) (6.3)	(5.1) (3.5)	(3.4) (2.2)	Rao <i>et al</i> (1994)
China	Swamp	ESH	6	6	46	26	22	Wang <i>et at.</i> , (1994)
Italy	Medit.	FSH	89			2.43	1.91	Zicarelli <i>et al.</i> , (1997)

SLT after slaughter, [†] first time superovulation, * after repeated superovulation

Some of the observations. related to embryo transfer in buffalo, made during the Ph.D. studies (Misra, 1996) were:

- the loss of nearly 53.2% ova/embryos, even after slaughter of buffaloes, may be due to ovulation of oocyte within the follicle, degeneration of oocyte before ovulation, mistaken assessment of lutenized follicle as CL, failure of fimbria to pick up the ova when ovulations coincide with very high oestrogen levels or a high E2/P4 ratio, inability of the fimbria to trap ova from enlarged superovulated ovary, leakage of the flushing medium along with ova/embryos through the utero-tubal junction to the peritoneal cavity, difficulties in locating hatched blastocysts in the flushings, premature entry of ova/embryos into the uterus of buffalo and their expulsion, and human error.

- all the ova/embryos reached uterus around 5.5 days after the onset of superoestrus, suggesting that the ideal time for non-surgical embryo collection in the buffalo appears to be between days 5.5 to 6.0 of the superovulated cycle (oestrus = day 0).

- embryo development in superovulated buffalo shows considerable variation as two, three or even more stages of embryos (8 cell to expanded blastocyst) were recovered from the same donor buffalo and the rate of development appeared to be 24 to 36 h faster than cattle.

- a significant negative correlation ($r = -0.87$; $P < 0.05$) between the E2/P4 ratio on day 1 and total embryo recovery indicates that high E2 levels with a prolonged duration of rise may lead to reverse peristalsis in the fallopian tube with a consequent loss of some embryos in the peritoneal cavity.

- comparison of lactating add dry animals flushed (86.4% vs 100%; $P < 0.05$) indicated an adverse effect of lactational stress on a number of animals responding with > 2 CL. Interestingly, however, lactation did not affect the yield of total and viable embryos.

- our study on the effect of superovulation and embryo collection on milk production suggests that milk production was not affected by superovulation and embryo recovery.

- out of the 91 recipients which received 112 embryos, 24 conceived with an overall pregnancy rate of 26.4 %.

- the pregnancy rates in autumn (20.7%) and winter (29.0%) were not significantly different.
- embryo transfer in recipients following either natural or PGF_{2α} induced oestrus resulted in similar conception rates (25.0% vs 28.2%).
- the effect of oestrus synchrony on the pregnancy rate indicated that the highest pregnancy rate (40.7%) was obtained in the group of recipients that were closely synchronized with the donor. However, when recipients were out of phase by $> \pm 12$ h with the donors, the pregnancy rate declined.
- The size of CL in the recipients ovary tended to influence the pregnancy rate. The lowest pregnancy rate of 15.8% was found with small size CL, it increased to 25.0% and 31.8% when the CL were of medium and large size respectively. However these differences were not significant
- transfer of embryos into either the right or left uterine horn had no effect on the pregnancy rate.
- among embryo stages, early morula and compact morula produced 17.9% and 28.3% pregnancy rates respectively and were not significantly different,
- the grade I embryos resulted into a significantly higher (60%) pregnancy rate than grade II (25%) or grade III (21.6%) embryos.
- the per cent viable embryo recovery was considerably affected by the bull semen used for AI of donors. Thus, viable embryo recovery rates with bulls Nos. 46 (84.4%) and 43 (65.1%) were significantly higher than bulls Nos. 42 (32.6%), 44 (35.1%) and 47 (43.7%).
- frequency distribution of total number of ovulations in superovulated buffaloes indicated that an overall 10.3% buffaloes failed to respond to superovulatory treatment and about half (48.6%) had poor superovulatory response (0-5 CL). Only less than 1/3 (29.9%) buffaloes which responded with 8 or more ovulations can be considered as good responders.

The presence of only one third of the follicle pool in buffalo and higher atresia compared to cattle (Danell, 1987) is reported to be a reason for poor superovulatory response (Jainudeen, 1989; Kamonapatana, 1990). However, if absolute numbers are taken into consideration, the adult buffalo still has a pool of over 20000 follicles to respond to superovulatory treatment. There is a need to study ovarian function and folliculogenesis in the buffalo, to evolve a buffalo specific superovulatory protocol.

In vitro embryo production

More recently, the emerging technology of *in vitro* production has become a viable alternative to producing embryos by superovulation, especially in cows and buffaloes which respond poorly to gonadotrophin stimulation. Additionally, this technique can be used to salvage and conserve the genetics of elite animals which are infertile or sterile.

Since the first publication (Pieterse *et al.*, 1988) on repeated use of ultrasound guided transvaginal oocyte collection or ovum pick-up (OPU), active research in the field of OPU and *in vitro* fertilization (IVF) has led to the possibility of collection of as many as 1000 oocytes resulting in 300 *in vitro* produced (IVP) embryos from a normal cow (Kruip *et al.*, 1991). Attempts have also been made to use this technology in buffaloes (Boni *et al.*, 1997; Galli *et al.*, 1998). Advantages of OPU-IVF technology over conventional ET are:

OPU and IVF	Embryo transfer
The technique requires no hormonal stimulation of the donors	Superovulation of donors is necessary and accounts for about half of the total cost of flushing
Aspiration of follicles can be done twice a week over a long period	Flushings can be repeated at an interval of 8-10 weeks only.
In a period of one flushing, 10 to 12 OPU sessions can be applied which results in about 14 transferable embryos and subsequently 6 pregnancies	The average outcome per flush is 5.5 transferable embryos which results in 3 pregnancies on an average
IVP embryos can be produced from nearly all animals	Nearly 1/3 animals do not produce viable embryos.
Prepubertal donors can be used.	Donors are used after puberty.
Pregnant donors up to third month of pregnancy can be used for OPU.	Only non-pregnant donors can be used.
Infertile animals can be used for OPU	Infertile animals are not used.
Requires no detailed information on the reproductive status of the donor.	Information on the reproductive status of the donor is essential.
Since the fertilization of oocytes takes place under laboratory conditions the oocytes of same donor can be fertilized individually with semen of any particular top sire.	Only one sire can be used on a donor at one time.

Steps in the OPU-IVF technology: The IVP technology is based on several assisted reproductive techniques: i) the collection of immature oocytes with the help of an ultrasound scanner with a transvaginal probe and needle guidance system and a suction pump (OPU), ii) *in vitro* maturation of the oocytes (IVM), sperm capacitation, *in vitro* fertilization (IVF), the development of the fertilized oocytes into transferable embryos or *in vitro* culture (IVC), embryo sexing, freezing and transfer.

Collection of oocytes: Following local anaesthesia, the OPU procedure starts with the insertion of an ultrasound probe into the vagina. The ovary is visualised on a monitor and follicles > 2 mm diameter are punctured using a transvaginal curvilinear transducer to guide a 55 cm long IF-19 gauge single lumen needle to which a vacuum of 80-100 mm of Hg is applied.

Selection of oocytes: The aspirant is immediately searched for immature cumulus oocyte complexes (COCs) under stereozoom microscope, which are placed in a 35 mm petri dish containing 3 ml of washing media (TCM-199 with 10 % FBS). COCs are evaluated under 100 x magnification according to the degree of investment with cumulus cells and the quality of cytoplasm. Only those COCs classified as grade I and II, which have the ability to undergo maturation and embryonic development are selected for maturation. Grade I COCs have 4 or more layers of compacted cumulus cells surrounding zona pellucida of oocyte and evenly granulated cytoplasm. Grade II COCs do not have much compaction with 1 to 3 layers of cumulus cells surrounding the zona pellucida of oocytes and evenly granulated cytoplasm. Grade III COCs have fibrous cumulus layer surrounding zona pellucida, while Grade IV COCs are devoid of cumulus cells.

Maturation of oocytes: Among several commercially available culture media, the most commonly used medium for maturation seems to be TCM 199. However, for *in vitro* culture, several different media such as TCM 199, CRJ aa, mSOF, KSOM, and Menezo's B2 with various modifications have been used. Very recently, commercially prepared media for bovine IVF have been launched in the market (Taneja and Yang, 1998). The culture conditions adopted during *in vitro* maturation of oocytes significantly influence the fertilization rate and subsequent embryonic development which vary among different laboratories.

In brief, about 5 to 40 COCs are added to 50 µl droplets of maturation medium. The droplets are covered with mineral oil and preincubated under maturation conditions for at least 2 h (38.5°C, 5 % CO₂ and 95 % air atmosphere with 95-100 % humidity) prior to incubation of COCs for 24 h. At the end of incubation period, the oocytes emerge at the same stage of development as they are released at the time of ovulation in the live cow.

Preparation of sperm: Most mammalian sperms must reside in the female tract for a period of several hours to undergo capacitation before they acquire the ability to fertilize an egg. Heparin which is believed to be involved in the natural process of capacitation, has been successfully used for *in vitro* capacitation of sperms. Frozen thawed semen of the desired sire is subjected to either swim up or percoll gradient method, essentially to separate live and progressively motile sperms. These highly active spermatozoa are pelleted by centrifugation and then resuspended in the media and incubated with 10 to 100 µg/ml heparin to bring about the capacitation.

Fertilization of oocytes Group of 5 oocytes is placed in 48 µl droplets of fertilization medium. Two µl sperm suspension (final concentration in droplet = 1×10^6 spermatozoa/ml) is then added to each drop which is incubated for 16 to 18 h.

Culture of embryos. Developing the fertilized oocytes to an embryonic stage which can be transferred to the uterus of a cow buffalo requires culturing in specified conditions for at least 6-7 days. Complex, serum supplemented culture media are used for this. In recent years, the technique of culturing these developing embryos along with other cell types (Trounson *et al.*, 1994) has improved the success rate of embryonic development and reduced the harmful effects of the waste products of metabolism released in the culture system. After washing the fertilized oocytes for 2 h in development medium, 20 fertilised oocytes are placed in each 50µl droplet of oviductal cell culture having 20 to 25 vesicles. After 48 to 96 h of culture, 50µl of fresh medium is added to the droplets containing the embryos. After 7 days of culture, the embryos reach a stage of development which can be transplanted to uterus of recipient or can be cryopreserved for future use. On an average 20 percent embryos develop up to a stage suitable for transfer, which could reach up to 40-50 percent.

Prepubertal calves as oocyte donors: Collection of oocytes from prepubertal calves offers considerable potential to accelerate the genetic gain by reducing generation interval. Subsequent to the birth of the first IVF calf through this technology (Armstrong *et al.*, 1992), 43 percent pregnancy rate and 33 percent live births from calf oocytes have been reported (Armstrong *et al.*, 1997). Others have reported use of this technology (Revel *et al.*, 1995; Taneja *et al.*, 1998).

Success rates following OPU-IVF Recovery of cumulus oocyte complex (COC), viable embryos produced and pregnancy rate following transfer of IVP embryos as reported by different workers are listed in Table 2. The pregnancies established by Boni and associates (1997) could not succeed to term and the first buffalo calf using this technology was produced by Galli *et al.*, (1998).

Table 2. Comparison of IVP work in buffaloes

Description	Bani <i>et al.</i> (1997)	Galli <i>et al.</i> (1998)
Animals	4	2
Sessions	47 (twice/ week)	48 (twice/week)
Oocytes	213 (4.49)	198 (4.1)
Cleaved	72 (1.5)	59 (1.2)
Embryos collected	39 (0.8)	26 (0.5)

Like *in vivo* technique, the efficiency of production of buffalo embryos *in vitro* is also poorer than cattle (Table 3) and needs to be researched further for improvement.

Table. 3 Comparison of OPU-IVF work in cattle in the Netherlands

Description	Kruip <i>et al.</i> , (1994)	Zuid <i>et al.</i> (1944)*	Lansbergen (1997)
No. of animals	8	82	63 (23 preg. heifers)
No. of sessions	Once/week (48)	Twice/week (111)	Twice/week (1881)
No. of oocytes	104	6,314	14,275
No. of oocytes cultured	104 (<i>in vivo</i> culture in ewe)	5,432	
No. of transferred embryos	25	2,877	2,357
Pregnancy rate			
Fresh (%)		44%	43%
Frozen(%)		31%	43%

*Personal communication

In general, the success rate and potential of this in cattle is given below:

No. of oocytes aspirated per ovary	8 - 13
No. of oocytes aspirated per donor	15 - 25
% of oocytes fertilized	40 - 80
% of oocytes reaching transferable stage	15 - 30

Considering a weekly collection of about 10 to 20 oocytes from each donor, 1.5 to 3.0 viable embryos can be produced per donor per week. These results clearly suggest that OPU-IVF technology can be used as an efficient tool to conserve valuable genetic resources in the bovine and is a viable alternative to conventional embryo transfer technology.

Factors affecting the success of IVP programme

- Abnormalities in protein synthesis in oocytes from unstimulated calf ovaries is indicative of cytoplasmic deficiencies and incomplete ooplasmic maturation affecting developmental competence of oocyte
- Stimulation of the prepubertal heifer donors with gonadotrophins improves the developmental competence of retrieved oocytes.
- Embryonic loss is higher after implantation of calf embryos. However, the fertilization and developmental rate of cow and calf oocytes are not different.
- Individual donor variation in terms of ovarian response is still incompletely understood. Donor pre-selection for IVP is an option to obtain best results. Three days interval between collection results in a higher number of embryos per collection than 4-7 days interval.
- Nutrition of oocyte donor can influence blastocyst yield.

Sexing of Embryos

Predetermination of sex of preimplantation embryos has been an important application in domestic species for livestock breeding and conservation. The male is the first choice in meat industry and also in artificial insemination programmes for production of semen. The female is the choice animal for the dairy industry, hence production of female and male sexed embryos in the proper proportion is desirable.

Methods of sex determination

The ideal way for predetermining sex will be the separation of spermatozoa containing the X or Y chromosomes and insemination of the donors with either of these to produce desired sex. However, this technique has not yet been used commercially because of the very slow rate of separation of spermatozoa and the lack of accuracy. Another approach has been sexing of embryos which has been attempted by several non-invasive and invasive methods.

Non-invasive methods

In this approach the integrity of the embryo is maintained for successful implantation into the recipients. These methods fall into two categories.

Detection of H-Y antigen: This involves the immunological detection of male specific antigen referred to as H-Y antigen, and the accuracy of sexing is about 85 percent.

Measurement of X-linked enzyme activity: Mammalian females bear two X chromosomes and the males have one X chromosome. However, to maintain an equivalent number of genes between the sexes, one of the X chromosomes of the female is inactivated at an early embryonic stage. Sexing is based on the measurement of cellular concentration and activity of certain X-linked enzymes which is twice in case of female embryos than male embryos. This method is also not 100 percent accurate and there is a problem of embryonic mortality.

Invasive methods

In this method, the zona pellucida of embryo is punctured and blastomeres are separated and subjected to:

Karyotyping: The technique involves the biopsy of a small number of cells of an embryo and their metaphase chromosomes are examined microscopically for the detection of two X chromosomes or one Y-chromosome. Though the technique has 100 % accuracy, it is time consuming. Also, obtaining metaphase chromosomes from the biopsied embryonic cells is difficult and it is not possible to transfer sexed embryos into recipients on the same day.

DNA probing: It also involves biopsy of embryo to determine the sex by localization of DNA sequences present on the Y-chromosome. The total DNA of the biopsied cells of the embryo is hybridized to a labelled sequence of DNA that is specific to Y-chromosome. Positive hybridization result indicates the presence of Y-chromosome, indicating a male embryo. The reduced viability of the embryo and need to cryopreserve embryo after biopsy (as the process is time consuming) are the limitations of this technology.

Polymerase chain reaction (PCR): A satisfactory method for embryo sexing should be accurate, sensitive, specific, rapid, reproducible, and should not affect embryo viability. All the above approaches fall short of one or more of the requirements for a successful embryo sexing technique. The development of the Polymerase Chain Reaction (PCR) and its application to amplify Y-chromosome specific (male specific) DNA sequences, directed by primers with a thermostable DNA polymerase from a small amount of DNA of one or more blastomeres (biopsied from an embryo), meet all the above requirements for a successful sexing technique.

This technique requires two oligonucleotide primers complementary to the sequences present on the target DNA. The procedure involves repeated cycles of heat denaturation of the DNA (94°C for 30 sec), annealing of two specific primers (60°C for 30 sec) and extension of the hybridized primers on the target DNA sequence with the help of thermostable DNA polymerase enzyme.

(72°C for 45 sec). Each successive cycle doubles the number of target DNA and amplifies to the levels where it can be easily detected by agarose gel electrophoresis and visualised under UV light after staining.

In vitro produced buffalo embryos have been sexed with high accuracy using this technology (Apparao *et al.*, 1993; Totey *et al.*, 1996; Apparao and Totey, 1999).

Cloning of Embryos

Revolutionary opportunities in both animal breeding and research were created by the development of procedures for nuclear transfer in mammals (McGrath and Solter, 1983). It is now almost a decade since these procedures were first applied in farm animals (Willadsen, 1986) and during the period there has been considerable improvement in these techniques (Barnes *et al.*, 1990).

Embryo multiplication in mammals is achieved by fusion of a donor (embryonic/somatic) cell to an oocyte or zygote from which the genetic material has been removed (cytoplast). In farm animal species, the recipient cell is usually a secondary oocyte, obtained following ovulation *in vivo*, or by *in vitro* maturation of oocytes recovered from ovarian follicles either at slaughter or by transvaginal oocyte pickup. Enucleation is accomplished either by splitting the oocyte in half (Willadsen, 1986) or by direct removal of the second-metaphase chromosomes by aspiration of that portion of the cytoplasm that is adjacent to the polar body, by use of a DNA specific fluorochrome to identify the chromosomes (Campbell *et al.*, 1996). The former method is simple. However, it reduces the volume of the cytoplasm significantly and may influence both the pattern (Evsikov *et al.*, 1990) and frequency of development (Greising *et al.*, 1994) while the latter method results in the removal of a smaller proportion of cytoplasm.

Following enucleation, the genetic material from the donor cell is introduced into the enucleated recipient cell. In farm animals, the most commonly used method is the application of a DC electrical pulse at right angles to the plane of contact between the two cells (Willadsen, 1986). This causes a localised transient breakdown of the plasma membranes and fusion of the two cells and also activates the recipient oocyte. More recently, particularly with the use of smaller cells as nuclear donors, direct injection of the whole cell into the recipient has been used successfully (Collas and Barnes, 1994; Ritchie and Campbell, 1995). This procedure can also induce oocyte activation (Ritchie and Campbell, 1995). Following embryo reconstruction, development to the blastocyst stage is usually accomplished in the oviduct of a temporary recipient (sheep) as *in vitro* culture is believed to be less effective (Campbell and Wilmut, 1994). This reconstructed embryo can serve as a donor embryo in subsequent recloning and hence this technique has immense potential in conservation of genetic resources.

This technique sparked considerable interest in the cattle embryo transfer industry, however attempts to commercialise this technology in the last decade did not succeed because of the poor efficiency of the cloning technology and the abnormality of the cloned calves. In 1997, the production of Dolly, the first mammal cloned from an adult cell, sparked a second wave of interest in this technology. The promises behind this new version of technology are: 1) the possibility to duplicate an unlimited number of copies of animals using somatic cell lines, 2) the possibility of genetic manipulations of the cell lines prior to cloning (including xenotransplantation to produce human organs from animals, especially pig) and, 3) the feasibility of cloning a proven valuable animal.

In the buffalo, cloned embryos have been produced by nucleus transfer of buffalo foetal fibroblasts and oviductal cells into enucleated bovine oocytes (Kitiyanant *et al.*, 2000), however an attempt to use swamp buffalo oocytes and bovine quiescent cumulus cells failed to produce

morula/blastocyst (Nguyen *et al.*, 2000). Cloned progenies have been produced using embryonic (sheep: Campbell *et al.*, 1996; cattle: Sims and First, 1993; Stice *et al.*, 1996; pig: Prather *et al.*, 1989); foetal (sheep: Wilmut *et al.*, 1997); cattle: Cibelli *et al.*, (1998) and adult cells (sheep: Wilmut *et al.*, 1997). The efficiency of the cloning technology is still low and further research is needed before this technology can be commercialised.

Use of embryonic stem (ES) cell technology for the genetic manipulation of livestock

A major technical advancement in agricultural sciences has been the capacity to insert foreign genes into organisms and establish their stable integration into the germ line. Production of transgenic animals provides a method for sudden and directed mutations in cattle, swine, sheep, goats and other animal species. This methodology causes an abrupt change in the genetic make-up of the animal but is, in essence, not really different from crossbreeding or genetic selection in its result. There are numerous potential applications of transgenic methodology to develop new or altered strains of livestock. Practical applications of transgenics in livestock production are enhanced prolificacy and reproductive performance, increased feed utilisation, modified carcass composition, improved milk production and/or composition and increased disease resistance. By enhancing disease resistance transgenic animals can help to salvage genetics in the face of disease outbreak.

Transgenic animals have been produced by pronuclear injection of foreign DNA into one-cell embryos. Unfortunately, these manipulations greatly reduce embryonic survival to approximately 25-35 percent. The efficiency of producing offspring carrying foreign genes by this technique ranges from 0.04-1.7 percent (Rexroad and Pursel, 1988). Another major drawback of microinjection is that any number of copies of the gene can be inserted randomly into the genome. This random insertion can result in difficulties in controlling gene expression. The use of retroviral vectors and liposome carriers to transfer foreign DNA into domestic livestock have been less successful than pronuclear injection (Murray *et al.*, 1988). As a result of these problems, the search is on for other methods for manipulating the mammalian genomes. Perhaps, the most promising method is the use of embryonic stem (ES) cells as vectors for producing the desired mutations (Wheeler *et al.*, 1995).

Establishment of ES cells from a wide variety of species will allow more flexibility in direct genetic manipulation of livestock as well as gene regulation studies and developmental biology research. Isolation of embryo-derived cell lines has already been reported from preimplantation embryos of the mouse, Syrian golden hamster, mink, rat, pig, cattle and sheep (reviewed by Wheeler *et al.*, 1994). This technology, besides its use in producing clones, can also be used to produce disease resistant breeds of livestock.

Modification of disease resistance through ES cell transgenesis

The potential to increase disease resistance by introducing specific genes into livestock is a very interesting aspect of ES cell transgenics. The identification of a single gene in the major histocompatibility complex (MHC) that was able to influence the level of immune response was instrumental in the recognition of the genetic basis of disease resistance/susceptibility (Benacerrat and McDevitt, 1972). The importance of selection in increasing disease resistance in livestock has been realised during the last two decades. It is now known that many aspects of disease resistance and/or disease susceptibility in livestock are genetically determined (reviewed by Lewin, 1989). The application of transgenic methodology to specific aspects of the immune system will provide opportunities to genetically engineer livestock with superior disease resistance. A specific example of the application of transgenesis to enhance disease resistance in livestock is the production of swine that are resistant to influenza. Mouse fibroblast cell lines that contained the Mx⁺ protein were found resistant to infection with influenza virus (Haller *et al.*,

1981). The Mx cDNA was been microinjected into the pronucleus of porcine zygotes to produce a pig strain resistant to influenza virus (Muller *et al.*, 1992). This manipulation is an excellent example of how transgenesis may be used to increase disease resistance in livestock.

Gamete intra-fallopian tube transfer

Gamete intra-fallopian tube transfer (GIFT), an assisted reproductive technology which is routinely used in human infertility, has recently been used to produce pregnancies in mares (Carnevale, 1996; Carnevale and Ginther, 1995, Hinrichs *et al.*, 1998a; Hinrichs *et al.*, 1998b). This technique involves collection of oocytes by transvaginal, ultrasound-guided aspiration, short-term culture of the *in vivo*-matured oocyte followed by transfer of the oocyte to the oviduct of a recipient mare (Carnevale, 1996). The recipient mare is generally inseminated prior to and after oocyte transfer. Pregnancy rates from the transfer of oocytes collected from normal mares were 11 out of 12 in one study (Carnevale, 1996; Carnevale and Ginther, 1995) and 9 out of 17 in another (Hinrichs *et al.*, 1998a). In contrast, the pregnancy rate after transfer of oocytes from older mares was only 30% (Carnevale *et al.*, 1995). The GIFT procedure is currently being used by several commercial embryo transfer centres, and pregnancy rates are likely to improve with continued use and further refinement in this technology.

Sperm microinjection

Pioneering research involving the microinjection of hamster and human sperm into the cytoplasm of hamster oocytes (Turczynski *et al.*, 1994) eventually led to the development of a valuable technique called "assisted fertilization". This technique of intracytoplasmic sperm injection (ICSI) is widely used in human medicine, and in some cases, has nearly replaced conventional *in vitro* fertilization of human oocytes. ICSI-derived offsprings have been produced in cattle (Goto *et al.*, 1991), horse (Squires *et al.*, 1996; Cochran *et al.*, 1998; McKinnon *et al.*, 1998) and humans (Palermo *et al.*, 1992). ICSI has also been attempted in dog (Fulton *et al.*, 1998) and pig (Kim *et al.*, 1998).

Potential usefulness of ICSI in assisted fertilization in livestock appear limitless, as even testicular and epididymal-derived sperm are capable of decondensing in ooplasm (Uehara *et al.*, 1977) and producing viable human embryos and offspring. ICSI of nonviable sperm has ever? resulted in the production of live calves (Goto *et al.*, 1991).

Assisted hatching

It is known that the extended exposure of human oocytes and embryos to IVC can impair their ability to implant (Edwards *et al.*, 1984). Subsequently, it was suggested that some apparently normal IVF-derived embryos may be unable to hatch from their zonae pellucide and that by artificially breaching the zona by zona drilling (Cohen *et al.*, 1992); Gordon and Talansky, 1986) or partial zona dissection (Cohen *et al.*, 1989), implantation rates could be enhanced (Cohen *et al.*, 1990). It is interesting to speculate that reductions in pregnancy rates of IVF bovine embryos compared with *in vivo*-derived embryos (Loony *et al.*, 1994) could be caused by culture-related hatching inhibition. Loskutoff *et al.*, (1993) found that partial zona dissection improves the hatching frequencies of cryopreserved bovine blastocysts produced *in vitro* and that co-culture conditions (e.g. medium and cell type) during early development can affect survival after thawing. This technique could also be of significant use for propagation of endangered species.

Conclusion

There is an urgent need to apply available and emerging new biotechnology comprising embryo transfer, embryo sexing, separation of X and Y bearing sperm, ovum pick up, *in vitro* fertilization

and embryo culture, nuclear transfer, gene transfer, embryo stem cell technology etc., which are sweeping the globe especially since the last two decades, to revolutionize buffalo productivity in the twenty first century.

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OPTIMIZATION OF RABBIT PERITONEAL FLUID AND BUFFALO FOLLICULAR FLUID CONCENTRATION FOR *IN VITRO* MATURATION, FERTILIZATION AND CLEAVAGE OF BUFFALO OOCYTES.

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Abstract: A study was conducted to optimise rabbit peritoneal fluid (rPF) and buffalo follicular fluid (bFF) concentration for *in vitro* maturation, fertilisation and cleavage of buffalo oocytes. A total of 407 good quality oocytes retrieved from the ovaries brought from slaughter house were allotted to five different concentrations of rPF, in such a manner that the rPF group contained a total of 177 and bFF 230 oocytes, respectively. Both rPF and bFF were diluted with normal saline (NS) to provide concentrations of 75%, 50%, 37.5%, 25%, and 20%, respectively and the same added to the media. Neat rPF and bFF served as controls. After following the standard processing protocol, the oocytes were matured as mentioned above under standard incubation condition of 5% CO₂, 95% humidity and 38°C for 24 hours. The sperms were prepared as per standard procedure and were inseminated in fertilisation TALP medium. The percent maturation, fertilisation, cleavage and development up to blastocyst formation was recorded after putting the cleaved embryos in TCM added with oviductal cell media. Fairly good maturation rate was observed in all the concentrations of bFF with control providing the maximum. However, the fertilisation rate in all concentrations except 37.5% was not encouraging. While comparing these concentrations for percent cleavage rate and blastocyst formation only two groups i.e. Neat bPF=bFF (control) and 75% bFF provided a reasonable level of satisfaction. In the case of rPF, it was observed that only neat rPF is desirable for producing embryos under *in vitro* conditions, as none of the dilutions with NS provided a satisfactory level of maturation or development of embryos.

Keywords: Buffalo oocytes, maturation, fertilisation, cleavage

Introduction

Several biological fluids, such as egg-saline medium (Dowling, 1949), serum (Brock and Rowson, 1952), follicular fluid (Sreenan *et al.*, 1968) and rabbit peritoneal fluid (Collos *et al.*, 1991, Chung *et al.*, 1992, Singh and Dhanda, 1997 and Malik *et al.*, 1999) have been used with varying degrees of success for *in vitro* maturation (IVM) culture of oocytes in different farm animal species. The rationale for using these media in developing countries including India, weigh heavily on the most commonly used medium (TCM-199 supplemented additives) that has to be imported and consequently enhances the cost of embryo production,

Chauhan *et al.*, (1937) obtained 57 per cent maturation by replacing 40 per cent TCM medium with buffalo follicular fluid (bFF) while studying maturation of buffalo oocytes. Through the use of this method Singh and Dhanda (1997) achieved a very high rate of IVM (97%) of buffalo oocytes in rPF. However, the quantity of these fluids either from the ovaries or live rabbits is very limited and warranted dilution without disturbing the osmolarity and pH, crucial for *in vitro* culture. The present study, therefore, was conducted to optimize the concentration of bFF and rPF post-dilution with normal saline (NS) for embryo production from buffalo oocytes.

Materials and Methods

Collection of ovaries and recovery of oocytes

Buffalo ovaries were collected from a slaughter house in Delhi and brought to the laboratory within 6-7 hours of slaughter, in a thermos flask containing sterile physiological saline supplemented with benzyl penicillin and streptomycin sulphate. The same were washed in

Dulbecco's Phosphate Buffer Saline (DPBS) (Sigma Aldrich, St. Louis, USA) twice and in 70 per cent ethanol for 30 seconds. These were again washed with DPBS thrice. After removal of excess tissue from the ovaries, oocytes were retrieved by using a 18 gauge hypodermic needle fitted to a 5 ml plastic syringe from 2-6 mm surface visible follicles. The oocytes were transferred to a petri dish containing TCM-199 with 3 mg bovine serum albumin (BSA). The oocytes surrounded by 4-5 layers of Cumulus Cells Complexes (COC's) were selected for maturation.

Collection of bFF and rPF

Buffalo follicular fluid and rabbit peritoneal fluid were collected as per procedure described by Chauhan, *et al.* (1997) and Malik, *et al.* (1999), respectively, with slight modifications in recovery of bFF. After collection, the fluid was centrifuged at 1500 rpm for 10 minutes and filtered through 0.22 µm filter and stored at -20°C until use.

***In vitro* maturation, fertilization and co-culture**

With a view to find the optimum level of bFF and rPF, different concentrations of these fluids namely, 75, 50, 37.5, 25 and 20 per cent were prepared with normal saline. Neat rPF and bFF served as the control. One hundred microlitre drops for each dilution from bFF and rPF were prepared in 35 mm sterile petri dishes (Torsons, India) and covered with sterile CO₂ saturated warm light paraffin oil. A cluster of 4-6 oocytes was inoculated and incubated at 38°C with 5 per cent CO₂ and 95 per cent humidity in each microdrop for 24 hours. The maturation rate was assessed on the basis of expansion of cumulus cells and the presence of polar body.

Fresh, good quality buffalo semen was washed thrice in pre-incubated mDM medium containing 2.5mmol caffeine. The sperm suspension was subjected to swim up test for 30 minutes. This fraction was re-suspended in mDM having 3 mg/ml BSA. The sperms were capacitated by exposing them to 25µmol of calcium ionophore for 20 seconds and left in the fertilization drop consisting of fertilization TALP with epinephrine and hypotaurine. In each fertilization microdrop, 5-10 matured oocytes were inseminated and incubated for 6 hours under the same conditions as mentioned above. Cumulus cells were separated from the oocytes and these were washed in co-culture medium (TCM-199 + 10% bES). The microdrops (100 µl) were prepared in petri dishes and covered with liquid paraffin oil. To each microdrop 5-10 oocytes were transferred and co-cultured with oviductal cell monolayers prepared separately under incubation conditions as per the standard procedure described by Chauhan *et al.* (1997). The culture medium was changed daily and the cleavage rate was examined on second day of culture.

Results

The data on *in vitro* maturation, fertilization and co-culture of buffalo oocytes in different dilutions of bFF and rPF are presented in Tables 1 and 2, respectively. Highly satisfactory maturation was achieved in bFF upto 50 per cent dilution with normal saline. In the remaining 3 dilutions, the same ranged between 70.00 to 80.41 per cent with no definite pattern in maturation. However, maximum fertilization rate was recorded in 37.5 dilution that differed significantly ($P < 0.05$) from all the groups except in the 75 per cent dilution. All other groups did not differ from each other.

Table I. *in vitro* maturation, fertilization, cleavage and development upto morulla/blastocyst stage of buffalo oocytes in different concentration of bFF

Media groups	Mean±SEM oocytes put for maturation (n)	Mean±SEM oocytes matured (n)	Percent oocytes matured	Mean±SEM oocytes fertilized (n)	Percent oocytes fertilized	Mean±SEM oocytes cleaved (n)	Percent oocytes cleaved	Mean±SEM morulla/Blastocyst developed (n)	Percent developed to M/B
Gr. I = 100% bFF	5.75±0.31 (46)	5.5±0.19 (44)	96.43 ^a ± 2.34	3.00±0.28 (24)	54.17 ^b ± 3.82	3.00±0.27 (24)	100.00 ^a ± 0.00	1.75±0.31 (14)	56.25 ^{ab} ± 6.05
Gr. II = 75% bFF + 25% NS	4.75±0.16 (38)	4.50±0.19 (36)	95.0 ^{ab} ± 3.27	2.5±0.19 (20)	56.25 ^{ab} ± 4.89	1.75±0.16 (14)	75.0 ^{ab} ± 0.45	1.25±0.16 (10)	75.0 ^a ± 9.75
Gr. III = 50% bFF + 50% NS	4.25±0.31 (34)	4.0±0.27 (32)	95.0 ^{ab} ± 3.27	2.00±0.00 (16)	51.67 ^b ± 3.63	1.25±0.31 (10)	62.5 ^{ab} ± 15.67	0.75±0.31 (6)	18.25 ^c ± 3.0
Gr. IV = 37.5% bFF + 62.5% NS	4.25±0.49 (34)	2.75±0.73 (22)	70.0 ^c ± 15.5	2.00±0.60	68.33 ^{ab} ± 5.87	0.75±0.31 (6)	50.0 ^b ± 13.36	0.25±0.16 (2)	33.3 ^{bc} ± 21.1
Gr. V = 25% bFF + 75% NS	5.0±0.27 (40)	4.0±0.27 (32)	80.4 ^{abc} ± 4.6	1.75±0.164 (14)	43.33 ^b ± 2.67	0.75±0.16 (6)	50.0 ^b ± 13.36	0.25 ± 0.16 (2)	33.3 ^{bc} ± 21.1
Gr. VI = 20% bFF + 80% NS	4.75±0.16 (38)	3.50±0.19 (28)	73.75 ^{bc} ± 3.1	1.50±0.19 (12)	43.75 ^b ± 6.05	1.00±0.00 (8)	66.67 ^{**} ± 8.96	0.00±0.00 (0)	0.00 ^d ± 0.00

^a Uses harmonic mean sample size = 8

^{abc} Figures having different superscripts differ significantly (P<0.05)

Table 2. *In vitro* maturation, fertilization, cleavage and development of buffalo oocyte up to morula/blastocyst stage in different concentration of rPF

Media groups	*Mean±SEM oocytes put for maturation (n)	Mean±SEM oocytes matured (n)	Percent oocytes matured	Mean±SEM oocytes fertilized (n)	Percent oocytes fertilized	Mean±SEM oocytes cleaved (n)	Percent oocytes cleaved	Mean±SEM oocyte developed to M/B (n)	Percent oocytes developed to M/B
Gr. I = 100% rPF	5.00±0.317 (30)	4.17±0.17 (25)	85.5 ^{ab} ±6.76	2.67±0.21 (16)	64.17 ^a ±5.07	2.17±0.17 (13)	83.33 ^a ±7.49	1.50±0.22 (9)	72.22 ^a ±12.0
Gr. II = 75% rPF+ 25% NS	5.67±0.33 (34)	5.00±0.26 (30)	88.73 ^a ±3.64	1.67±0.42 (10)	33.59 ^{abc} ±8.79	1.50±0.43 (9)	75.00 ± 11.08	0.50±0.34 (3)	22.22 ^{bc} ±16.0
Gr. III = 50% rPF + 50% NS	4.67±0.33 (28)	3.83±0.31 (23)	82.77 ^{ab} ±5.72	1.50±0.50 (9)	35.83 ^{abc} ±12.28	1.33±0.42 (8)	61.11 ^a ±20.03	0.17±0.17 (1)	8.33 ^c ±8.3
Gr. IV = 3.5% rPF + 62.5% NS	4.66±0.49 (28)	2.83±0.31 (17)	62.77 ^{bc} ±7.95	0.17±0.17 (1)	5.56 ^c ±5.56	0.00±0.00 (0)	0.00 ^c ±0.00	0.00±0.00	0.00 ^d ±0.00
Gr. V = 25% rPF + 75% NS	4.17±0.31 (25)	2.33±0.49 (14)	53.89 ^{cd} ±9.01	1.00±0.37 (6)	44.44 ^{ab} ±15.91	0.67±0.33 (4)	41.66 ^{ab} ±20.06	0.17±0.17 (1)	8.33 ^c ±8.33
Gr. VI = 20% rPF + 80% NS	5.33±1.41 (32)	2.33±0.76 (14)	37.50 ^d ±12.7 6	0.5±0.34 (3)	13.89 ^{bc} ±9.04	0.50±0.34 (3)	33.33 ^{ab} ±21.08	0.00±0.00 (0)	0.00 ^d ±0.00

• Uses harmonic mean sample size = 8

• ^{abc} Figures having different superscripts differ significantly (P<0.05).

Cleavage rate was found to be at a maximum in neat bFF followed by 75, 20, 50, 37.5 and 25 per cent dilutions, respectively. At the same time, no significant differences were found between the four dilutions as mentioned in the foregoing discussion, while these were observed to be different from the other two groups of 37.5 and 82.5 per cent dilution. Maximum morula development was recorded in the 75 per cent bFF group followed closely by the neat bFF group. All cleaved oocytes from 20 per cent bFF group suffered some kind of developmental block and did not proceed further, although this group had shown about 67 per cent cleavage rate. The development in 50, 37.5 and 25 per cent bFF groups was also not up to desirable level. It would thus appear that bFF may be diluted in the ratio of 3:1 with normal saline for satisfactory cleavage and embryo development up to transferable stage.

The results from different dilutions of rPF with normal saline were not very encouraging. Although maturation rate up to satisfactory level was achieved in 50 per cent dilution, fertilization in all the dilution rates except in the neat rPF group was found to be far from satisfactory. The neat group provided maximum fertilization, cleavage and development up to the blastocyst stage.

Discussion

Our results on bFF are in agreement with those of Choi *et al.* (1998). Romero-Arendono and Seidel (1996), Das *et al.* (1996) and Chauhan *et al.* (1997), who reported satisfactory levels of maturation and cleavage rates in cows and buffaloes by replacing some part of the base medium i.e. TCM-199 with follicular fluid. Since none of these authors have studied embryo development in neat follicular fluid the comparison in a strict sense, with them and other workers may be out of place. At the same time, it is apparent that follicular fluid is competent to mature, cleavage and cause further development in the absence of TCM-199.

Saini (1994) reported a very high maturation rate ($92.2 \pm 1.25\%$) in rPF from goat oocytes. Similar observations have been recorded by Singh and Dhanda (1997) in a similar study on buffalo oocytes in rPF. However, Malik, *et al.* (1999) reported lower maturation and fertilization rate in goats based on cumulus cell expansion and male and female pronuclei formation. There is absence of published information on cleavage and subsequent development of oocytes up to morula/blastocyst formation where rPF has been used as a complete medium for in *vitro* development of embryos in farm species. Therefore success of peritoneal fluid in supporting oocyte maturation and co-culture, as observed in the present study is difficult to be compared. From the present study, it appears that rPF contains similar protein and other micronutrients, mimicing oviductal fluid (Iritani *et al.* 1971), which are essential for maturation and fertilization under in *vivo* conditions.

Conclusions

It was concluded that bFF may be used along with normal saline in the ratio of 3:1 for in *vitro* generation of embryos in buffaloes. However, rPF when diluted results in lowering the success rate in this species.

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CRYOPRESERVATION OF *IN VITRO* PRODUCED SWAMP BUFFALO BLASTOCYSTS BY VITRIFICATION METHOD USING ETHYLENE GLYCOL-BASED SOLUTION

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Abstract: This study was conducted to examine the *in vitro* survival of vitrified-thawed F₁ hybrid buffalo embryo produced *in vitro*. In total, 73 embryos at the early stage of blastocyst, blastocyst and expanded blastocyst were examined. The vitrification solution used was EFS40 and 10% EG; these were 40% ethylene glycol diluted in modified phosphate-buffered saline (mPBS) containing 30% Ficoll + 0.5 M sucrose and 10% EG was prepared with 10% ethylene glycol diluted with PBI medium. The embryos were exposed to the solutions in two-step method at room temperature; kept in the solution for 0.5 or 1.0 min, vitrified in liquid nitrogen and warmed slowly. When the early blastocysts were vitrified in EFS40 solution after 0.5 or 1.0 min of exposure, 88.23% and 61.53% of them were found to have re-expanded blastocoels and 58.82% and 30.8% had the ability to hatch from their zona pelucida within 72 hr on *in vitro* culture. Expanded blastocyst did not survive regardless of the exposure period. The results indicate that *in vitro* produced swamp buffalo embryos can be effectively vitrified by this simple method. However, refinement of the procedure is needed to improve the survival and *in vitro* development shall be investigated in the future.

Keywords: Swamp buffalo, embryos, fertilisation, cryopreservation, vitrification.

Introduction

The swamp buffalo has been an important animal for draft, meat and milk purposes. By using embryo transfer, *in vitro* fertilisation and other manipulations become possible. Production of embryos by totally *in vitro* procedures and birth of calves have been reported after transferring fresh embryos produced through fertilisation and development in culture of *in vitro* matured oocytes that originated from slaughter house into recipient caracows (Ocampo *et al.* 1996; Suzuki *et al.*, 1992; Madan *et al.*, (1994a,b)). Therefore, cryopreservation of these embryos plays a vital role in the practical application of this technology.

However to date, there have been only preliminary reports on the Freeze preservation of swamp buffalo embryos (Techakumphu *et al.*, 1989). In 1992, Misra and others reported a pregnancy rate of 15% and subsequently, Kasiraj *et al.* (1993) showed that both morula and blastocysts could be successfully frozen-thawed and transferred to establish pregnancies. These authors used a 1.4 M Glycerol solution as the cryoprotectant by a conventional method. However, there have been no reports on the vitrification method of swamp buffalo embryos.

In 1985, Rahl and Fahy reported the first successful vitrification of mouse embryos using VSI, composed of dimethyl sulphoxide (DMSO), acetamide and propylene glycol and one macromolecule. With this approach, however the toxicity caused by high concentrations of cryoprotectants is the biggest obstacle (Fahy *et al.*, 1984). Therefore, Kasai *et al.* (1990) developed a vitrification solution composed of ethylene glycol, Ficoll and sucrose which has a low toxicity. This was modified by a two-step exposure method using EFS40 to successfully vitrify mouse blastocysts (Zhu *et al.*, 1993).

To the best of our knowledge, vitrification of swamp buffalo embryos produced *in vitro* using EFS40 has not yet been reported. Successful vitrification of embryos have been reported in rabbit (Hasai *et al.*, 1992), bovine (Tachikawa *et al.*, 1993) and equine (Hochi *et al.*, 1994) embryos.

In the present study, *in vitro* development abilities of two *in vitro* produced swamp buffalo embryos vitrified in an ethylene glycol-based solution were examined. Here, we report the first vitrified-thawed early blastocysts that have been successfully hatched after further *in vitro* culture.

Material and Methods

Production of blastocysts *in vitro*

Ovaries obtained from Philippine native caracows at various ages, killed at a slaughterhouse, were brought to the laboratory in physiological saline (containing 100 i.u. penicillin/ml + 100 µg streptomycin sulphate/ml) at 29-33°C within 4-6 h of slaughter. Immature cumulus-oocytes complexes were aspirated from follicles of 2-8 mm diameter through a 18-gauge needle into a 5 or 10 ml disposable plastic syringe containing pre-warmed Dulbecco's phosphate buffered saline (Gibco Laboratories, Grand Island, NY), supplemented with calcium and magnesium chloride and modified with the addition of 3% Foetal Bovine Serum (FBS, Gibco). The aspirated oocytes were pooled, first in a plastic sterilized test tube before transferring to the petri dish using a Pasteur pipette. Using a heat polished haematocrit micropipette tube attached to a mouth controlled silicon tubing, selected oocytes were washed 2-3 times in a maturation medium (TCM-199, Sigma) supplemented with 10% Foetal Bovine Serum (FBS, Gibco). Approximately 10-15 oocytes were transferred into each 110 µl droplet of culture medium (TCM-Sigma Chem) supplemented with 10% FBS and antibiotic (100 IU/ml Penicillin G and 100 µg/ml streptomycin sulphate in a culture dish (Nuncelon 153066, Inter-med, Roskilde, Denmark) covered with mineral oil (E.R. Squibb & Sons, Inc., Princeton, NJ) cultured for 2-4 h.

One 0.5 ml straw of locally processed frozen semen obtained from one purebred Murrah bull, which was tested by artificial insemination was thawed in a water bath at 37°C for 15 seconds. Spermatozoa were washed twice in a Bracket and Oliphant solution (BO solution, Bracket and Oliphant, 1975) modified by the addition of 100 µg/ml Na pyruvate and supplemented with antibiotics by centrifugation at 1,600 rpm for 5 minutes each time, the sperm concentration was then adjusted to 20×10^6 cells/ml. The sperm suspension was diluted with an equal volume of BO solution supplemented with 6 mg BSA/ml 10 mM caffeine, 4 U/ml heparin, to give a sperm concentration of 10×10^6 cells/ml.

About 10 oocytes that have been subjected to maturation culture were introduced to the insemination medium of 100 µl droplets in a petri dish covered with a mineral oil (Squib). About 6-7 hours after insemination, oocytes with cumulus cells were washed 4 times in a pre-incubated maturation medium and transferred to a 100 µl droplet of development medium (TCM 199). The cumulus cells attached to the surface were not removed to form a monolayer. All the embryos were then cultured further on this layer, and those that developed into blastocysts 5-7 days after insemination were used. All incubations were done in a water-jacketed incubator with air temperature of 39°C and 5% CO₂.

Vitrification solution

The cryoprotectant used was (EFS40) ethylene glycol (Wako pure Chemical Industries, Osaka, Japan) which was diluted with 40% (v/v) in modified phosphate buffered solution (mPBS) containing 30% (w/v) Ficoll 70 (average molecular weight 70,000; Pharmacia, Uppsala, Sweden) as non-permeating agent + 0.5M sucrose (S-PB1) (Sigma Chemical Co., St. Louis MO) as a low molecular compound which causes embryo shrinkage by osmosis. The final concentration being 18% Ficoll and 0.3 M sucrose. This solution does not form ice during cooling to liquid nitrogen or after warming (Kasai, 1990). While 10% ethylene glycol was diluted in PB1 medium, The respective solution was then designated EFS40 and 10%EG, respectively.

Vitrification of blastocyst

Blastocysts were vitrified essentially by a two-step method as described for mouse (Zhu *et al.*, 1993) with some modifications. EFS40 solution was prepared in a 0.25ml plastic straw (A-201, instruments de médecine vétérinaire, l'Aigle, France), a column of 0.5M sucrose (~35mm) and a 2 columns of EFS solution (~3 and ~13 mm) were aspirated successively, separated by air, with a 1ml syringe connected by a small silicone tube, and the straw was held horizontally at 28-30°C. The 3 mm EFS column was used to prevent contamination of the 13 mm EFS solution with the S-PBI medium adhering to the wall of the straw. Embryos classified as early blastocysts, blastocysts and expanded blastocysts were then exposed to EFS40 for 0.5 or 1.0 minute after pre-equilibration with 10% EG for 5 minutes. One or two embryos were suspended in 10% EG solution at 28-30°C in a watch glass for five minutes and were then washed in the solution twice. They were transferred into the 13 mm EFS40 column, and then columns of EFS40 solution (~3mm) and S-PBI medium (~12mm) were aspirated, separated by air, before being sealed with the powder. The third EFS40 solution (3mm) was used to catch embryos that may have adhered to the wall of the straw during aspiration. The sealed straw was then immersed into the nitrogen. The half of the straw that included the EFS40 columns was rapidly immersed into the liquid nitrogen, followed by slow immersion of the rest of the straw, in order to prevent bursting of the straw (Kasai, 1990).

Recovery of vitrified embryos

After storage for 1 - 120 days, the straws were warmed slowly for 15 sec in air or rapidly in a water bath at 30°C. As the crystallised S-PBI in the straw began to melt (~5 sec), the opposite of the natural plug was clipped with scissors or straw cutter. The contents of the straw were expelled in a watch glass by flushing the straw with 0.8 ml S-PBI, using 1 ml plastic syringe or simply pushing the plug with a small steel rod and agitating gently. The embryos were then pipetted into fresh S-PBI at room temperature. About 5 minutes after being flushed out, the embryos were transferred to fresh mPBS.

Survival of vitrified blastocysts

To assess the survival of vitrified-thawed embryos, recovered blastocysts were washed twice and cultured *in vitro* in a culture dish with a feeder layer of cumulus cells in development medium in which *in vitro* fertilized embryos had been cultured for 5-8 days. The development medium had been replaced a day before thawing. The embryos were examined under a dissecting microscope and the number of embryos in which the blastocoel had re-expanded within 48 h of culture and the number that had hatched from the zona within 72 h were recorded as criteria for survival.

Results and Discussion

The results are summarised in Table 1. A total of 73 blastocyst stage embryos were used to examine the effect of cryopreservation by the vitrification method. All the embryos (100.0%, 73/73) were recovered after warming. When the blastocysts were recovered after warming, the embryos were shrunk and had collapsed blastocoel, therefore it would be difficult to assess the morphology. The result also showed that only 2 and 5 embryos exposed at 0.5 and 1.0 min exposure time, respectively had injured zona and almost all of them, 88.23% and 61.54% had intact zona after thawing. It was observed that a lower percentage of the vitrified embryos had cracked zona compared with freezing as revealed in the present results. This fracture damage is caused by non-uniform volume change from the solid liquid phase change and can be prevented by slow cooling and slow warming (Kasai *et al.*, 1996).

When early blastocysts were vitrified in EFS40 solution after 3.5 or 1.0 min of exposure, 88.23% and 61.53% of them were found to have re-expanded blastocoels and 58.82% early blastocysts subjected to exposure time at 0.5 min, have the ability to hatch from their zona pellucida within

72 h *in vitro* culture. However, when the exposure time was extended to 1.0 minute, only 30.8% hatched from the zona. The survival was very low (1-33.3%) when embryos were vitrified at the blastocyst stage, after 1.0 or 0.5 min of exposure, respectively. Expanded blastocysts did not survive regardless of the exposure period.

The present study indicates that *in vitro* produced embryos at the early stage of blastocyst development seem to be the least sensitive than blastocyst or expanded blastocysts. Preliminary results have been reported on the vitrification of bovine blastocysts produced *in vitro* (Yang *et al.*, 1992), in which embryos are equilibrated in several steps for longer periods, followed by exposure to vitrification solution. Thus it seems that the expanded blastocysts, compared with early stages need more time for sufficient permeation of the cryoprotectant, yet they are more sensitive to exposure to the vitrification solution. Similar results were also reported in frozen mouse embryos where the survival of expanded blastocysts and blastocysts was very low compared to that of early blastocysts (Massip *et al.*, 1984) as well as in vitrified rabbit embryos (Smorag *et al.*, 1989).

In the present study, embryos were first equilibrated in 10% ethylene glycol and briefly exposed in EFS40 solution. This may allow initial permeation of ethylene glycol into embryonic cells before vitrification in EFS40 that brought 50% survival rate. However, more permeation is harmful since the percentage of hatched blastocysts decreased after the duration of exposure was increased to 1.0 min (Table 1). The harmful effect of excess permeation may be attributed either to the toxicity of ethylene glycol or to the osmotic injury during removal of ethylene glycol from the cells after warming. The usual exposure temperature of vitrifying mouse embryos was 25°C, but we used 28°C-30°C room temperature. The high temperature might have also affected the decreased survival.

The expanded blastocysts, regardless of the exposure period, did not survive. It has been shown that the inclusion of macromolecules in the solution facilitates vitrification (Fahy *et al.*, 1984). Various macro-biomolecules exist in the cytoplasm, while Ficoll is present outside the cell. In the blastocoelic cavity of blastocysts, there are few macromolecules and the permeation of ethylene glycol required for vitrification of the cavity may be insufficient. The blastocoelic cavity is likely to be frozen, which may damage the cells. Miyake *et al.* (1993) and Shaw *et al.* (1991) reported that the survival of blastocysts decreased as the blastocoelic cavity enlarged and that longer exposure at low temperature improved the survival rate.

In conclusion, results showed that *in vitro* produced swamp buffalo embryos can be effectively vitrified with ethylene glycol solution. Vitrified-thawed early blastocyst has the ability to develop and successfully hatch *in vitro* after vitrification in EFS40 by a two step method. The simple methods can be useful for the cryopreservation of swamp buffalo embryos. However, more trials are needed to determine the optimum temperature of exposure in order to improve the survival rate. Embryo transfer of vitrified-thawed viable embryos can also be carried out in the future to assess the development *in vivo*.

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SYMPOSIUM - V

Biotechnology

Discussion

Q. B.M.A.Oswin Percra - With regard to embryo freezing, which is one of the new developments, what success rates are possible under controlled conditions and under field conditions?

A. A.K. Misra - The success rate was 26% pregnancies under farm conditions, But this particular report refers to the outcome of the use of our embryos supplied to the State centre in villages. Surprisingly they reported 51% conceptions with frozen embryos. This may not be applicable everywhere, because the scientist may have selected very good animals and he himself was a very experienced person. He used 50 to 60 embryos. But on a larger scale, if embryos are good, we should be able to get about 40% conceptions. The conception and pregnancy rates reported were possible because we have frozen about 50 to 65% good quality embryos out of the embryos we have collected. So we were left with only the poor quality embryos which we transferred and then these frozen embryos were thawed. If they were graded I, they became grade II and if they were grade II they became grade III. We have reported 6% conception with grade I embryos.

Q. B.M.A. Oswin Perera - With regard to AI, one of the advantages is that when the farmer detects a cow in heat, he can call the technician and get it done immediately. Here, we have to time it to 5 1/2 to 6 days depending on when you have collected the embryos. How do you arrange this logistically in the field situation?

A. A.K. Misra - In the field, we synchronise the animals, otherwise it is very difficult.

Q. A. Borghese - Do the embryos that you produced come from animals with a genetic value proven by performance and progeny tests? How did you conserve the embryos, with vitrification or by other methods?

A. O.P. Dhanda - These ovaries were collected from the slaughterhouse, where we have no control over the types of animals that come to the slaughterhouse, We have not used these embryos. We have gone only with blastocyst elements. They have not been transferred and preserved as such, because we want to synthesise whether this technology is useful. We are moving to work with the buffalo.

Q. A.D.N. Chandrasiri - I have also two questions. In one experiment I conducted in Sri Lanka with goat oocytes, I have compared the synthetic oviduct fluid and epithelial oviduct monolayer cell culture. In that experiment, I have found that oviduct fluid is superior to the other medium. There are various media used by scientists and the results depend on the location and the scientist. My question is, whether you have compared PFF and RPF with TCM 199 and whether you have done experiments with other media and if so what were the results? My second question is to do with head to head capacitation. Does the reaction take place with capacitated sperm or with acrosome reacted sperm? I ask this because to my knowledge capacitation takes place in the vicinity of the embryo, and as soon as the sperm capacitates, fertilization takes place.

A. O.P. Dhanda - I have not tried different combinations of media. But they are published in the literature. If you scan the literature a number of them use synthetic media. In Europe, most have tried MFM, KRV and MDM and others. But the best ones used optimally by all the workers is TCM 199. The question is that if you import this, the cost is very high. So the question was, can we substitute tissues with some cheap, readily available media for this purpose? So when we saw the report of the work with other species, we started to work on the buffalo, because it is a very valuable animal. To answer the second question, it is very difficult to separate between capacitation fluid and the acrosomal reaction.

Q. D.H. Duran - I was impressed with the results you have obtained using this medium. My question is, how did you compute the blastocyst development rate? Is it out of the total number of oocytes or the total number of oocytes that cleaved?

A. O.P. Dhanda - No. It is from the total number that fertilized. If you take the oocytes at the beginning, some will not mature and the number will be reduced.

Q. V.K. Gunawardena - Have you done any comparative studies with programmed freezing?

A. D.H. Duran - No. We do not have the programmed freezer.

Q. V.K. Gunawardena - Are there published work with which you can compare?

A. D.H. Duran - There was no information with embryos of buffaloes. Reports of work with other animals are available.

Q. A.D.N. Chandrasiri - In the slide on the IBEB efficiency, the hatching rate was 77%. This is higher than the blastocyst formation rate. How can this happen?

A. D.H. Duran - This was computed out of the number of embryos that cleaved. The blastocyst development was computed out of the total number of embryos that were subjected to *in vitro* fertilization. The hatching rate was calculated on the basis of the total number of blastocysts that developed.

A SURVEY ON BUFFALO REARING PRACTICES IN MATARA DISTRICT

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Abstract: A house to house field survey was conducted in 4 randomly selected assistant government agent (AGA) divisions (Weligama, Akuressa, Kamburupitiya and Devinuwara) in Matara district using a structured questionnaire to determine the systems of buffalo management and patterns of their utilization. There were 1421 buffaloes belonging to 407 holdings distributed in 21 grama niladhari divisions in the 4 AGA divisions. Farmer families involved in buffalo farming were 5.4% in the 4 AGA divisions. Total herd varied from 212 in Devinuwara to 489 in Weligama. Sex ratio of total herd favoured females at 1.0:2.6, while it approached 1:1 for calves indicating a greater disposal of mature males and the importance of buffaloes for milk (curd) production. Important feeding practices which were much better than expected comprised feeding of tree legumes (76.8%), unprocessed straw for cows and bulls (35.6% and 46.8%, respectively), straw silage (1.3%), concentrates (47.7%) and minerals (26.0%). Feeding practices were superior in Weligama and Devinuwara. Colostrum feeding, naval protection and deworming were also practiced, but there is room for improvement of these practices. Use of artificial insemination and vaccination for haemorrhagic septicaemia and foot and mouth disease were negligible except at Devinuwara, which also need further improvement. Buffalo curd fetched a better price than selling of liquid milk. Making of curd also solved the problems of lack of facilities for storage or immediate marketing of liquid milk. Indications are that, through low inputs and farmer awareness, milk production can be greatly improved in buffaloes with a great economic significance due to their multipurpose role in agriculture.

Keywords: Buffaloes, rearing, utilization, survey, Matara

Introduction

There is an estimated population of 16,000 buffaloes in the Matara district forming an integral part of the farming systems and rural life, with a multipurpose role in agriculture. The utilization of buffaloes for milk production varies greatly among different villages, depending on traditional farming practices and the demand and marketability of milk. Curd made particularly from buffalo milk has a greater consumer demand. In fact, buffalo curd made in Southern Sri Lanka, popularly known as Ruhunu Curd is of national significance for its taste and consumer demand. Buffalo dung being similar to cattle dung is used as fertilizer for crops. Fresh dung mixed with clay and water is also used as a surface sealant on rammed earth floors of dwelling houses in remote villages. However, the major economic importance of the buffalo in the rural farm situation is providing draught power in rice cultivation (Ryan *et al.*, 1981). Due to the escalation of costs of fuel and agricultural machinery and repair costs including the cost of spare parts during recent years, buffaloes have once again resumed an important role in the district.

Base line data on existing systems of management, production, breeding and nutrition, which are specific to the Matara District are scanty. However, a few reports covering the entire county or much larger areas, with little reference to Matara district are available (Kumaratilake and Buwanendran, 1979; Richards and Agalawatta, 1982; Siriwardene *et al.*, 1982; de Silva *et al.*, 1985). The objective of this study was therefore to collect some of the base line information on buffaloes in Matara district.

Materials and Methods

Identification of buffalo farmers and collection of data.

A house to house survey was conducted in the following four Assistant Government Agent (AGA) divisions in Matara district: Weligama, Akuressa, Kamburupitiya and Devinuwara (Table

(Table 1). Trained youth from the Grama Niladhari Divisions (GND) of the 4 AGA divisions conducted the survey. A single interview using a structured questionnaire was used to collect the information from all identified buffalo owners.

The main sections of the questionnaire were as follows:

1. Herd composition
2. Feeding practices
3. Calf management practices
4. Artificial Insemination (AI), vaccination and milking procedures
5. Utilization of milk
6. Marketing of milk

Microsoft Excel version 7 and Statistical Analyses Systems, Cary, USA (1995 version) were used for data management and statistical analyses.

Results and Discussion

Socio-economic profile

There were altogether 407 farmer families involved in buffalo farming in the 4 AGA divisions (Table 1). The number of farmers surveyed per AGA division varied from 73 in Devinuwara to 161 in Kamburupitiya. The highest of percentage of buffalo farmers (6.8%) was in Weligama, while the lowest (3.4%) was in Akuressa. These percentages are normal for Matara district and fairly comparable with the values obtained from the Kiralakelle marsh (Seresinhe and Pathirana, in Press). Only a small proportion (10%) of the buffalo farmers depend on their animals for regular cash income. The others generally obtained benefits such as draught power, milk for family consumption, dung and occasional sales of surplus stock. This situation is common in Sri Lanka (Wijeratne, 1962). Ranawana (1995) and Abeygunawardena *et al.* (1992) also observed similar benefits from cattle farming.

Table 1. Distribution of buffalo farmers in 4 Assistant Government Agent (AGA) divisions

AGA Division	No. of GN ¹ Divisions	Number of farmer families	% of total families in AGA division
Weligama	4	79	6.8
Akuressa	5	94	3.4
Kamburupitiya	5	161	6.0
Devinuwara	3	73	5.4
Total	21	407	
Mean		19.4	5.4
± SD		11.2	3.5

¹GN – Grama Niladhari

Size and composition of buffalo herd

Herd composition of buffaloes owned by farmers in each of the 4 AGA divisions are presented in Table 2. The total number of buffaloes was lowest in Devinuwara (212) and highest in Kamburupitiya (464). It appears that the total herd has been generally limited to the availability of land for grazing. Large extents of paddy lands abandoned due to frequent inundation with water from the Nilwala river, have been converted to traditional grazing grounds in Akuressa, Weligama

Table 2. Herd composition of buffaloes in each of the 4 AGA divisions

AGA Division	Buffalo cows		Heifers		Male Calves		Female Calves		Total No. of calves		Stud bulls		Other bulls		Total herd	Herd size/ farmer
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		
Weligama	214	44.8	67	13.7	95	19.4	70	14.3	165	33.7	18	3.7	25	5.1	489	6.2
Akuressa	037	14.5	57	22.3	62	24.2	72	28.1	134	52.3	15	5.9	13	5.1	256	2.7
Kamburupitiya	112	24.1	112	24.1	82	17.7	114	24.6	196	42.2	11	2.4	33	7.1	464	2.9
Devinuwara	94	44.3	44	20.8	34	16.0	36	17.0	70	33.0	1	0.5	3	1.4	212	2.9
Total	457		280		273		292		565		45		74		1421	
Mean	114.3	31.9	70.0	20.2	68.3	19.3	73.0	21.0	141.3	40.3	11.3	3.1	18.5	4.7	355.3	3.7
±SD	63.9	13.1	25.6	3.9	23.0	3.1	27.7	5.6	46.7	7.8	6.4	1.2	11.4	2.1	122.6	1.6

Table 3. Feeding practices used by farmers in addition to natural grazing

ACA Division	Legume feeding		Straw feeding-dairy cows		Straw feeding-bulls		Straw silage feeding		Concentrate feeding		Minerals offered	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Weligama	70	88.6	23	26.2	33	41.7	1	1.3	59	74.7	25	31.8
Akuressa	67	71.2	29	26.5	44	46.8	0	-	15	16.0	5	5.3
Kamburupitiya	127	78.8	42	21.9	53	32.9	2	1.2	62	38.5	9	5.6
Devinuwara	50	68.4	50	67.7	48	65.7	2	2.7	45	61.6	47	61.4
Total	304		144		178		5		181		86	
Mean	76	76.8	36	35.6	44.5	46.8	1.25	1.3	45.25	47.7	21.5	26.0
±SD	20.59	21.29	19.9	20.46	19.20	20.29	0.95	0.56	27.50	29.07	19.3	23.1

and Kamburupitiya AGA divisions. As a result, the total number of buffaloes tended is be larger in these areas. The extent of such grazing land is limited in Devinuwara and the total number tended to be smaller. However, the herd size per farmer was lowest in Akuressa, while it was highest in the Weligama AGA division. The mean herd sizes for river type and crossbred buffaloes per farmer were 2.0 and 10.8 respectively in the present study, which agrees with the findings of de Silva *et al.*, (1985).

The total number of calves was lowest in Devinuwara (33.0%) and highest in Akuressa (52.31%). Buffalo cows made up the highest proportion (44.8%) in Weligama and lowest (14.5%) in Akuressa. The proportion of breeding stud bulls varied from 0.5% in Devinuwara to 5.9% in Akuressa. A normal sex ratio of 1.0:1.1 (males:females) for calves only, widened in favour of females (1.0:2.5) in the total herd due to greater disposal of males from among mature animals (1.0:6.2). These male:female sex ratios were higher than the ratios reported by Silva *et al.* (1985). The high sex ratios in favour of females for Matara district can be explained on the basis of the greater emphasis on the production of buffalo milk (de Silva *et al.*, 1985) for curd. But dry cows are also used for work in the paddy fields (Seresinhe and Pathirana, 1999) in Matara district. However, this finding is in contrast to the findings of Robinson (1977), who found that 80-100% buffaloes in Indonesia were primarily used for crop cultivation. The findings of this study confirm that buffalo rearing in the Matara district is regarded as a dairy enterprise, which is in agreement with the findings of Abeygunawardena *et al.* (1995) in relation to dairy cattle.

Feeding practices

Table 3 shows the number and percentages of farmers practicing different feeding methods in AGA divisions. In general most of the farmers practiced the recommended methods of feeding, except for the practice of feeding of straw silage, which made the feed superior when compared with the feeding practices of farmers in Kiralakelle marsh (Seresinhe and Pathirana, in Press). This may have been the result of extension work done by youths, who had received training under the Integrated Rural Development Programme (IRDP). Comparing the 4 AGA divisions, feeding practices in Devinuwara were always superior followed by Weligama. The feeding practices, utilising tree legumes as well as straw and even concentrates were superior to the normal standards. Farmers fed tree fodder (68.4-88.6%) to buffaloes and the system of feeding was the same during both wet and dry seasons. Rice straw has been fed more to bulls than to cows except in Devinuwara, following the age old tradition. However this practice will be more useful for milking cows under the grazing conditions with indigenous cattle in the area (Pathirana *et al.*, 1996). The use of straw silage in feeding was minimal. Low adoption of straw silage feeding is also in keeping with low adoption of conservation methods with forage crops in general.

Concentrates and minerals were also offered to buffaloes in these areas. This could be considered as a very rare feature in cattle feeding, especially in Matara District. In fact, the greater attention to feeding of buffaloes observed in surveyed areas could have been due to the impact of youth extension services. This is a special situation created by youths because generally neat cattle are given greater care in feeding management, as buffaloes were mainly reared under more extensive management conditions (Seresinhe and Pathirana, in Press). This change in feeding could be used as an example in extending its application to other areas to improve national milk production. Buffaloes as a species, is also known to have a greater ability compared with other species, to thrive on poor quality roughage (Bhatia, *et al.* 1979). It is encouraging to observe that the practice of straw, concentrate and tree legume feeding exists in this region. Pathirana (1984) demonstrated the importance of supplementation of straw when used as a basal diet for milk production in buffaloes, while Jayasuriya (1982) emphasized the benefits of feeding treated straw to buffaloes.

Table 4. Calf management practices used by farmers in 4 AGA divisions

AGA Division	Colostrum feeding		Naval Treatment			De-worming					
	No.	%	Western Method	Eastern method	Other Methods	Total	%	Western method	Eastern Method	Total	%
Weligama	79	100	38	21	1	60	76.0	48	8	56	70.9
Akuressa	83	88.3	5	34	0	39	41.5	38	5	43	45.7
Kamburupitiya	155	96.3	46	64	0	110	23.6	84	10	94	58.4
Devinuwara	68	93.2	12	13	13	38	68.3	16	48	64	87.7
Total	385		101	132	14	247		186	71	257	
Mean	96.2	92.6	25.3	33	3.5	61.8	52.3	46.5	17.8	64.3	65.7
±SD	4.1	3.9	14.4	16.5	1.2	19.1	21.0	5.9	3.5	19.6	15.5

Table 5. Use of artificial insemination, vaccination and milking practices

AGA division	AI		Vaccination		Milker (Gender)					
	No.	%	No.	%	Male s	%	Female s	%	Mixed	%
Weligama	2	2.5	0	0	NA ¹	NA	NA	NA	NA	NA
Akuressa	1	1.1	0	0	50	53.2	22	23.4	8	8.5
Kamburupitiya	16	9.9	0	0	88	54.7	44	27.3	16	9.9
Devinuwara	39	53.4	53	72.6	45	61.6	4	5.5	0	0
Total	58		53		183		70		24	
Mean	5.27	16.7	13.3	18.2	61.0	56.5	23.3	18.7	8.0	6.1
±SD	5.16	21.40	23.0	31.4	19.2	3.7	16.4	9.5	6.5	4.4

¹NA - Not Applicable**Calf management practices**

Calf management practices are given in Table 4. Colostrum feeding was satisfactory reaching 100% in Weligama, but there is room for improvement of this very important calf management practice in other areas particularly in Akuressa (88.3%). Traditional methods were more popular among the farmers with regard to prevention of navel infection, except in Weligama, while in Devinuwara 52.3% of all farmers adopt one of the methods. For de-worming, the use of western method was more popular than traditional methods, except in Devinuwara with 65.7% of all farmers deworming the calves using western drugs.

Use of artificial insemination (AI), vaccination and milking practices

Many workers found that the use of AI as a method of breeding buffaloes was negligible (Jellinek and Avenill, 1982). This is not surprising considering the difficulties that are encountered in heat detection under the present systems of management. However, 53.4% farmers in Devinuwara used AI for breeding purposes, as only 0.51% of the buffalo population in the survey sample were stud bulls. But the use of AI was negligible in other 3 divisions (Table 5). It was found that 18.2% of the buffalo farmers owned crossbred buffaloes compared to 1.2% who had only river type buffaloes in Matara district (de Silva *et al.*, 1985). The interest in cross breeding and the use of AI were evident in the district. Animals were vaccinated against HS and FMD only in Devinuwara. Buffaloes being more susceptible to HS, the findings are of grave concern.

Milking was a male dominated activity (56.5%) compared to females (18.7%), but a higher percentage of females in Akuressa (23.4%) and Kamburupitiya (27.3%) participate in this activity.

Milking, utilization of milk and marketing problems

All farmers who participated in the survey, milked their buffaloes at least once daily. The selling price of fresh milk ranged from Rs. 12-15 per litre. The selling price of curd ranged from Rs. 25-50 per pot depending on the volume of milk in the pot. Curd fetched a better price than liquid milk, although manufacture of curd involved additional work. However, the advantage of curd production was that it helped to overcome the difficulties experienced in the immediate disposal of liquid milk and the lack of storage facilities to prevent milk spoilage.

Data on utilization and marketing problems relating to milk are presented in Table 6. Most farmers in Akuressa (65.9%) milked animals only to produce curd for home consumption, while in Weligama most farmers (64.6%) used milk for home consumption as curd and sold the excess milk in liquid form. Means for all AGA divisions indicated that 32.3% farmers preferred to milk cows only to produce curd for home consumption, while 5.2% of farmers only sold their milk as curd.

Table 6. Utilization and marketing problems of milk

AGA Division	Home use only as curd (1)		Sale of milk only for curd (2)		Only curd sales		More Problems with rains		More problems with fresh milk vs curd		Quality/ shelf life problems	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Weligama	4	5.1	18	22.8	2	2.5	58	73.4	63	79.8	73	92.4
Akuressa	62	65.9	0	0	1	1.1	78	83.0	89	94.7	87	92.6
Kamburupitiya	33	20.5	0	0	1	0.6	133	82.6	63	39.1	151	93.8
Devinuwara	28	38.4	21	28.8	12	16.4	61	83.6	51	69.9	63	86.3
Total	117		39		16		330		266		374	
Mean	31.8	32.3	9.8	12.9	4.0	5.2	82.5	80.7	66.5	70.9	93.5	90.8
±SD	20.6	22.3	9.8	13.1	4.6	6.5	30.1	4.2	13.9	20.4	34.3	26.0

Of the most prevalent problems relating to the marketing of milk in all AGA divisions (90.8%) were related to quality and shelf life. Marketing problems of milk in general (both fresh milk and curd) were more acute during periods of rain (80.7%) than with those relating to fresh milk when compared with curd (66.5%). Pathirana *et al.* (1995) also reported that with Ruhuna curd quality and marketing problems occurred mainly during rainy seasons. Lower temperature, increased humidity and decreased consumption of milk during rains appear to be the major factors affecting the quality and marketability of milk and its products during rainy spells.

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PRELIMINARY SURVEY AND STUDY ON UP-COUNTRY DRY ZONE BUFFALOES

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Abstract: A survey was conducted to determine management systems, purpose of rearing and reproductive performance of buffaloes in the up-country dry zone. The sample comprised 120 buffaloes from three randomly selected Veterinary ranges. Animals were physically evaluated and a questionnaire was filled during visits to the farms. Data were analyzed with SAS. The majority of the buffalo farmers have only a primary education and are mainly engaged in small-scale vegetable and paddy farming. The availability of pastureland is limited. Income gained by buffalo rearing is low. Extensive management with range feeding and tethering was practiced. The average herd size is six. The purpose of buffalo rearing was to assist in ploughing and paddy harvesting. On average, 96% of farmers used buffaloes for land preparation in terraced paddy lands, called the 'Helmalu' system, where vegetables and root and tuberous crops are cultivated. The mean work period was 5.5-hours/day. The indigenous buffalo is the common breed in Sri Lanka, apart from the crossbreds, and the average body condition score is around three. The average herd composition is 17.5 % calves, 22% heifers, 43% cows and 14.5% males.

Milking is neglected in most places. The average milk yield is less than one liter per day and the lactation length did not exceed four months. The age at first calving was 48.7 months and calving interval was 23.6 months. The prevalence of reproductive problems seemed to be low, while seasonal breeding was evident. While a few nutritional problems exist, gastro-intestinal parasitism and FMD were reported to be concurrent diseases. A few farmers have access to veterinary services. Although there is a high potential to develop buffalo production in these areas, awareness of the farmers on scientific approaches was significantly low. Farmers should be motivated to use buffaloes for milk and other utilities. Further research will be of great assistance to uplift the socio-economic conditions of up-country dry zone buffalo farmers.

Keywords: Management system, performance, up-country dry zone,

Introduction

The Lanka buffalo plays a significant role in the rural economy of Sri Lanka, providing chiefly animal power for tillage and also being a source of milk and meat to a varying degree depending on the location. However, information regarding buffalo production patterns in the country is scanty. Results of a few surveys carried out in the recent past (Kumaratilake and Buwanendran, 1979; Ryan *et al.*, 1981; Richards and Agalawatte, 1982; Siriwardane *et al.*, 1982; de Silva *et al.*, 1985; Abeygunawardana *et al.*, 1996) have been reported. These provide an insight to some of the aspects of the production systems and performance in some characteristics in limited areas of the country. A study on buffalo nutrition in relation to the Agro-climatic zones (Ranawana *et al.*, 1996) has been done in mid-nineties covering all agro-climatic zones except the hill-country.

Currently, there is great enthusiasm with regard to the more efficient utilization of buffaloes in the country. Availability of baseline data on the existing systems of management, breeding, feeding, reproduction and disease status etc, on an island-wide scale is of importance in the formulation of development plans. Only a few studies have been done on management practices and other parameters of up country, dry zone buffaloes. According to our experience in conducting teaching programmes on farming practices with students since 1997, we have come across many buffaloes in this area in very good body condition. The Up country dry zone which has an average temperature of 27°C, average relative humidity of 65% and an average rainfall of 1500-2000 mm facilitate the well being of animals. As there is no published information on upcountry dry zone buffaloes, it was felt that it is very important to carry out a survey on these buffaloes to fill the gap.

Materials and Methods

The area surveyed included three randomly selected veterinary ranges in up country dry zone, namely Haputale, Welimada and Bandarawela. Thirty buffalo farmers from the Haputale veterinary range, 12 from Welimada range and 8 from the Bandarawela range were personally interviewed. Data were collected using an open-ended questionnaire. This study was carried out from September 1999 to January 2000. The data collected were analyzed by statistical software package, MINITAB.

Results and Discussion

Socio-economic condition of farmers

Twenty eight farmers (93.3%) interviewed were involved in livestock husbandry as a part-time occupation. The majority (71.4%) were engaged in small-scale farming such as paddy and vegetable cultivation, while the remainder were engaged in other activities such as buying and selling vegetables and salaried employment both in government and private sector. Only two farmers were engaged in livestock husbandry as a full time occupation.

Most of the farmers included in the study had only a primary education (Figure 1). Paddy cultivation is usually possible during Yala (south-west monsoon, September to May) season with the help of monsoon rains and water for irrigation. During Maha season (April to September), farmers resorted to vegetable, root and tuber crop cultivation. The income from both activities was seasonal. None of the farmers have a regular income from their animals. Their income from the animals also shows a seasonal variation depending on the demand for animals in draught purpose.

All the farmers included in the survey had their own lands with a majority (86.7%) having ownership of one acre, while the rest owned land in excess of one acre. None of the farmers had separate pasture or grasslands.

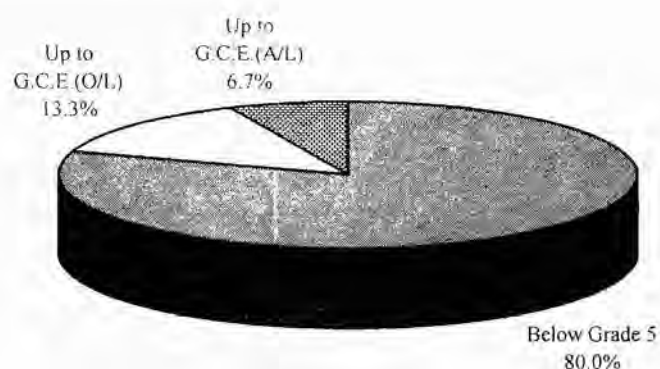


Fig. 1 Education Level of Farmers

Details of the animals

The animals were of the indigenous type, known as the Lanka buffalo (*Bubalus bubalis*) was the most common (85%) type found in this area. Others (15%) were crossbred animals mainly crosses of Murrah and Surti buffaloes.

Most of the animals included in the survey had a high body score of around three. Most of the animals were reared under an extensive management system with free range grazing. Some

animals grazing were kept under a semi-intensive management system, where tethering was practiced. None of the animals were given concentrates. On average, the herd comprised 17.5% calves, 28% heifers, 40% cows and 14.5% males. Among the males, only 10% were castrated animals. The average herd size was six.

Utilization of buffaloes

Ninety percent of farmers used their animals for draught purposes such as land preparation, ploughing and paddy harvesting in terraced paddy land known as 'Helmalu' system, which is a characteristic feature in the up country region. The animals are also used in land preparation for vegetable, root and tuber crop cultivation. Few farmers (6.7%) used their animals for mixing clay for brick making. The mean work period was 5.5 hours/day. This is relatively longer when compared to practices in the other areas. This may be due to the favourable climatic conditions of the zone, which reduces the heat stress of the animals.

Only a few farmers (3.3%) milk their animals. They animals are hand-milked once a day. The majority of them use the milk only for their own consumption, while the others sell after mixing with cow milk. The average milk yield was less than one litre and the average length of the lactation period was 3.6 months (Figure 2). None of the farmers included in the survey reared buffaloes for meat purposes.

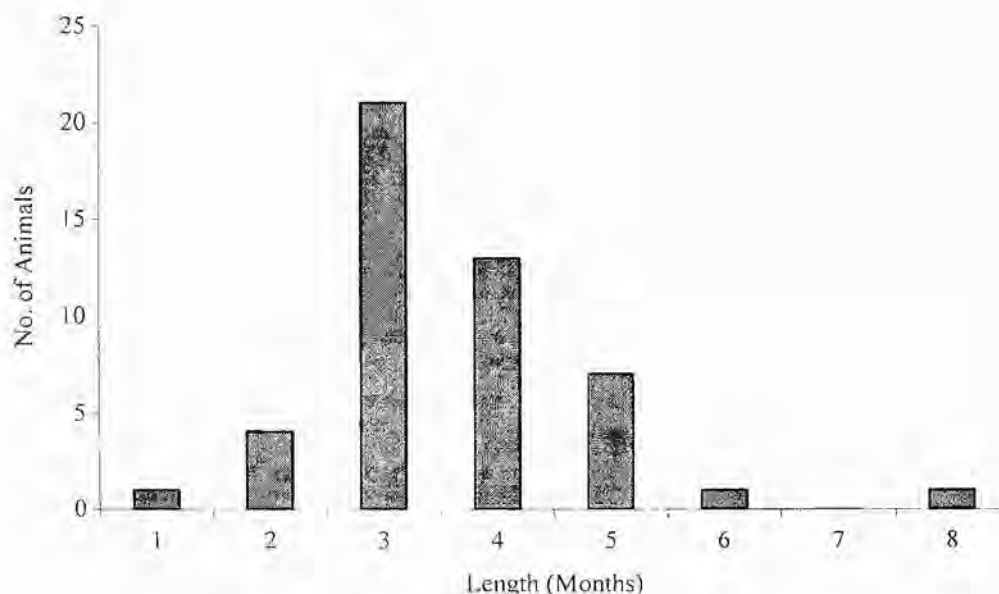


Fig. 2 Length of lactation

Reproductive status

None of the farmers use artificial insemination as a method of breeding for buffaloes. Reasons for this are, the difficulty in detecting heat under the extensive management system, the non-availability of buffalo semen and low preference for artificial insemination. The average age at first calving was 48.69 months (Figure 3). The average calving interval was observed as 23.6 months (Figure 4). Generally, reproductive problems seemed to be low while seasonal breeding was observed.

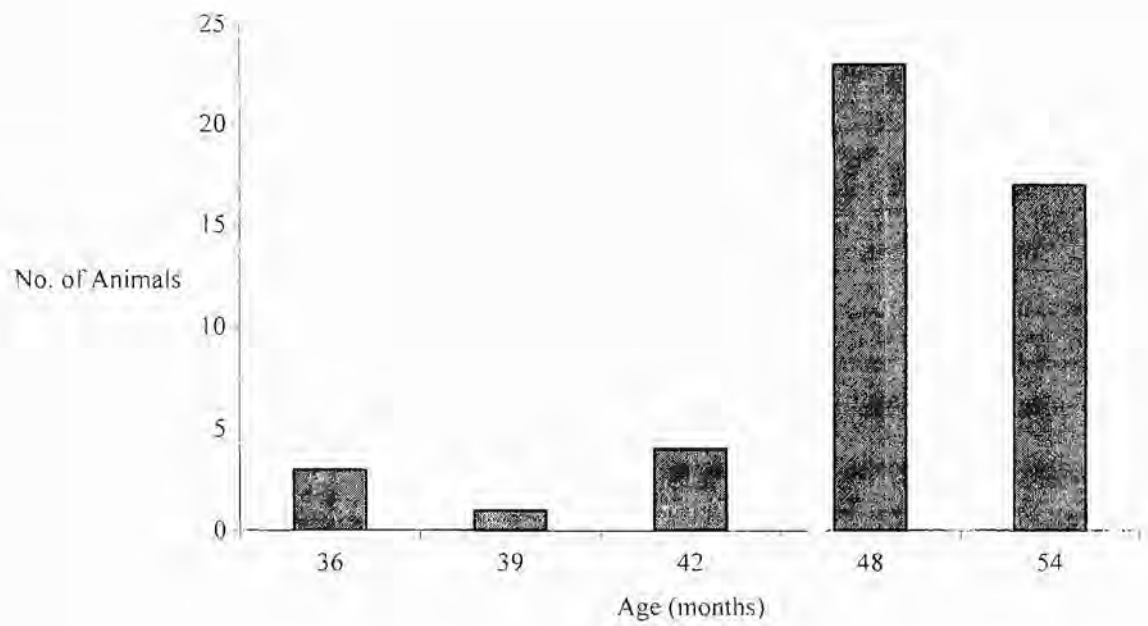


Fig. 3 Age at first calving

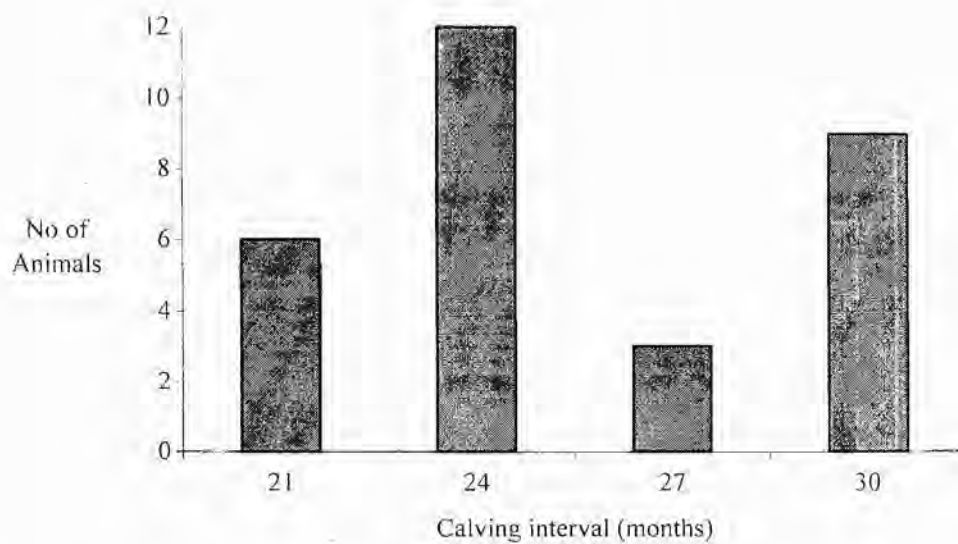


Fig. 4. Calving interval

Health status

In addition to some nutritional problems, gastro intestinal parasitism and foot and mouth disease were reported as common concurrent diseases. Only few farmers (40%) had access to veterinary services. The buffaloes are vaccinated mainly against the FMD.

Conclusions

The survey revealed some interesting features on buffalo production in up country dry zone. Although the buffalo population at present is low, as the incidences of diseases is not a significant problem in the area, the buffalo population can be increased with the introduction of scientific management practices and the profitable use of dairy products. Further genetic upgrading will be beneficial and profitable to the farmers rather than maintaining the local breed. Although there is a high potential to develop buffalo production, the awareness of the farmers on benefits of adopting scientific approaches is significantly low. Farmers should be encouraged to milk their animals. Further research and studies will be of great assistance to uplift the socio-economic conditions of upcountry dry zone buffalo farmers.

Acknowledgements

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Questionnaire for preliminary survey and study on up country dry zone buffaloes

1. Details of the farmer

- 1.1 Name :
- 1.2 Veterinary Range :
- 1.3 Address :
- 1.4 Animal rearing (part time / full time) :
- 1.5 If part time, permanent employment
- 1.6 Education :
- 1.7 No. of family members :
- 1.8 Average income of the family :
- 1.9 Land availability :
- 1.10 Pasture / grass / other crops :

2. Details of the animal

A) General

- A.1 Type and number of animals

	1	2	3	4	5	6
Breed						
Age						
Sex						
Body score						
Skin colour						
Horn pattern						
Remarks						
- A.2 Type of management :
- A.3 Type of feeding :
- A.4 Concentrates if given (kg / day) :
- A.5 Purpose of rearing animals :

3. Reproductive status

- 3.1 Breeding method (natural / AI) :
- 3.2 Rate of conception / Repeat breeding :
- 3.3 Average age at puberty :
- 3.4 Age at 1st calving :
- 3.5 Calving interval :
- 3.6 Reproductive problems :

4. Production status

Milk

- 4.1 Length of lactation :
- 4.2 Frequency of milking :
- 4.3 Method of milking :
- 4.4 Cleanliness – (prior / post) :
- 4.5 Average milk yield :
- 4.6 Fate of milk – (selling / production / consume) :
- 4.7 Average income :
- 4.8 Udder health :

Meat

- 4.9 To where animals are sold :
- 4.10 Age at which animals are sold for meat :
- 4.11 Average income by meat (per head selling) :

Draft

- 4.12 What is the usage – ploughing / Harvesting
- 4.13 Average income :

5 Health status

- 5.1 Common diseases :
- 5.2 Frequency of access to veterinary surgeon :
- 5.3 Common drugs used :

STATUS OF WILD BUFFALOE IN NATIONAL PARKS AND THEIR ADVERSE EFFECTS ON HABITAT MANAGEMENT

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Abstract: The presence of large numbers of water buffaloes in National Parks has created a critical management issue, due to the degradation of pasturelands and water holes. Many species of herbivores (*Elephas maximus maximus*, *Axis axis ceylonensis*, *Cervis unicolor unicolor*) have lost their right to survive within the National Parks due to this habitat degradation. Of the 15 national parks in Sri Lanka four were selected for this study to evaluate the current status of wild water buffalo and their effect to the ecology of these parks. Using the direct count method around water holes and grasslands, a calculation was made of the number of wild water buffaloes in the parks. An assessment of the number of domestic water buffaloes, that were released into the parks during daytime was made on information obtained by questioning a number of cattle owners. Based on this information, the approximate numbers of the resident buffalo populations in parks were identified. The water buffalo population was categorized as wild, extremely feral, feral, semi feral or domesticated, based purely on the reaction toward the presence of humans and external morphological attributes such as the height, body size, general condition, horn size and horn forms of animals and abundance of hair in the neck region.

It was estimated that between 40,000 to 60,000 water buffaloes graze in these parks. The number of wild buffaloes is more or less around 1500. Buffaloes cause habitat degradation by competing for food with other wild herbivores, pollution of water sources and soil erosion, weed propagation through over grazing, genetic contamination and spread of disease. Therefore the elimination or at least reduction in domestic water buffalo numbers in National Parks is essential for prevention of habitat degradation and genetic contamination of wild water buffaloes. This study proposes a domestication program for such buffaloes outside the National Park, while preserving the wild or extremely feral population within the parks. This is a preliminary study and further studies are required on cytogenesis, population statistics and health to develop a classification system based on morphometrics.

Keywords: Wild buffalo, habitat management

Introduction

Sri Lanka is amazingly rich in biodiversity, due to its unique bio-geographic nature. Despite its small size, it provides the required habitat and the conducive climate for a tropical fauna and flora inclusive of a large population of water buffalo in protected areas. The protected areas under the jurisdiction of Department of Wildlife Conservation (DWLC) are basically of two types, (a) National reserves and (b) Sanctuaries.

National reserves are further categorized into different classes, based on the nature of land ownership, access for human activities and conservation strategies. National parks are one of the categories under national reserves. These national reserves and sanctuaries cover an area of 789790.15 ha or 12.03% of geographical area of Sri Lanka. A high proportion of Sri Lankan water buffaloes directly or indirectly depend on these reserves.

It was earlier thought that the Lankan buffalo was a descendant of buffaloes introduced in the 6th century BC by immigrants from India. However, the occurrence of fossil buffalo teeth in gem pits at a depth of 10 m below ground level and other fossiliferous deposits indicate their existence in Sri Lanka from prehistoric times. It would seem that the wild buffalo indigenous to the island were domesticated by the early agricultural settlers.

The question as to whether the Sri Lanka water buffalo is truly of wild or feral origin has been a subject of debate for among taxonomists. It has been reported that no wild buffaloes are to be

found in the Indian mainland, south of the Central Provinces. It seems probable that the wild buffaloes now inhabiting the forests and plains of many areas of the dry zone in Sri Lanka are the descendants of feral domesticated stock, originally imported into Sri Lanka by the ancient Sinhalese, from the grassy plains of Ganges. Except that they are more massive in size and aggressive, with heavier horns, they are almost indistinguishable from recent feral stock with which they breed freely (Phillips 1935).

However, there is enough scope for such a segregated buffalo population in the wild to acquire the broad properties of a 'taxon'. It is unfortunate that no attempt has been made so far to differentiate between the wild, feral and domestic buffaloes cytogenetically. Hence the wild and extremely feral water buffaloes in the wild are recognized simply as wild or as feral.

Material and Methods

The study was carried out in four National Parks (Wasgamuwa, Udawalawa, Lunugumwehera and Yala National Parks), out of the 15 national parks in Sri Lanka. The study was carried with the help of wildlife rangers and game guards of the Department of Wild Life Conservation (DWLC). The direct count method was used during the rain and drought periods, around the water holes and grassland. While carrying out the survey, a number of cattle owners were questioned and an assessment was made of the number of domestic water buffaloes, that were released into the parks during daytime. Based on this information, the approximate numbers of the resident buffalo populations in parks were identified.

The reaction toward the presence of humans and external morphological attributes such as the height, body size, general condition, horn size and horn forms of animals and the massiveness and abundance of hair on the neck region, and brand marks were considered as guidelines for the categorization of water buffalo into wild, feral, semi feral and domesticated types.

Pasture lands and water holes were examined to assess the damage done by buffaloes, the spread and extent of weeds and agricultural plants compared with the other areas, where water buffalo activities were minimal. The pattern of utilization of water holes and grasslands by other herbivores were observed with and without presence of water buffaloes.

Results

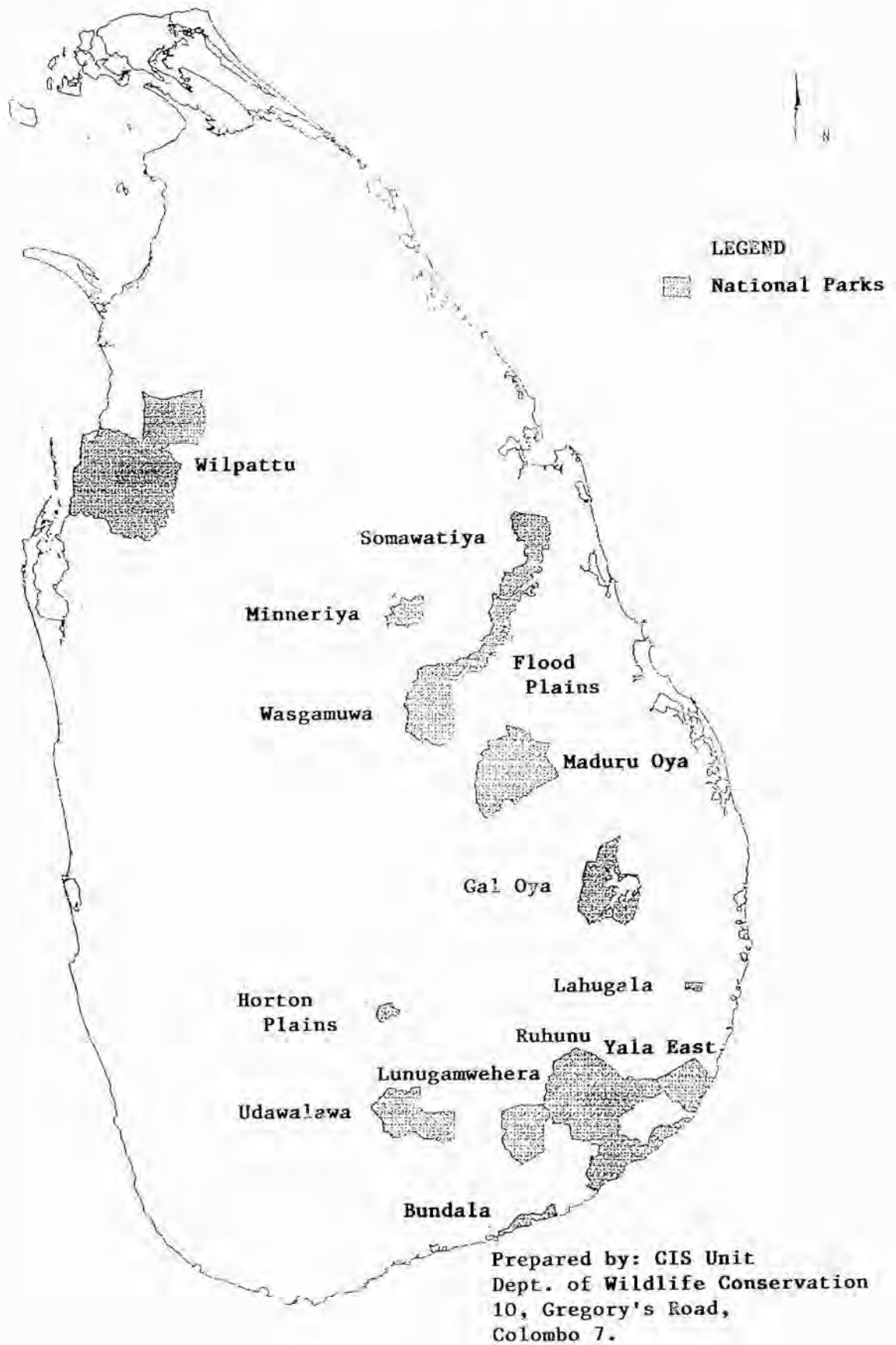
Table 1. Distribution of water buffaloes in selected National Parks.

Category	Yala	Udawalawa	Lunugamwehera	Wasgamuwa
Domestic and semi feral	12,000-16,000	15,000-18,000	10,000-12,000	10,000-12,000
Feral	2000-3000	2000-3000	500-1000	800-1200
Extremely feral/ wild water buffaloes	1000-1500	300-500	200-300	200-300
Total	15000-20000	17,000-22,000	11,000-13,000	11,000-14,000

The findings were based on direct observations done on the grasslands and water holes, where large number of buffaloes were available and compared with those in places where they were not available.

The effect of water buffaloes on the environment was observed mainly around waterholes, reservoirs, streams and rivers in the vicinity and in the grasslands. It was observed that there is considerable competition for food among herbivores. The competition for fodder becomes quite marked during the drought season. During the peak of the drought period, herbivores except water

NATIONAL PARKS UNDER THE DEPARTMENT OF WILDLIFE CONSERVATION



buffaloes regenerate naturally and weeds get the opportunity to overtake the pastures. The overgrazing of grasslands results in failure of natural regeneration of pasture. This provides a good opportunity for the non-fodder weed species such as *Lantana camera*, *Phyllathus polyphyllus* etc. to thrive. Mass movements of buffaloes also lead to soil erosion in river banks, reservoirs and water holes.

The adverse effect of buffaloes is seen particularly at the peak of the drought period when they use up available water resources. Buffaloes pollute the limited water that is left in the smaller reservoirs by wallowing and defecation. As a result elephants and other herbivores are not able to drink this polluted water.

Table 2. Extents of selected National Parks and population density of water buffaloes

National Park	Extent (ha)	Population density (Head/ha)
Yala	122,021	0.17
Udawalawe	30,821	0.48
Lunugamwehera	23,498.8	0.52
Wasgamuwa	36,948	0.32

Discussion

This study had no reliable identification key to differentiate between the wild, extremely feral, semi-feral and domestic water buffaloes. Except for the domestic buffalo, the rest had no brand marks as a guideline for identification. It was based purely on the reaction of animals toward the presence of humans and their external morphological attributes such as the height, body size, general condition, horn size and horn forms of animals and the massive body structure and abundance of hair on the neck region.

The first three categories were considered as residents of the park, while at times semi-feral water buffaloes that associated with the domestic herds moved away from the park. The crossbred progeny from matings between exotic breeds such as Murrah and Surti and the wild water buffaloes makes it more complicated to identify the wild water buffaloes morphologically. There is no doubt that such breeding with exotic breeds cause severe gene contamination.

It has been observed that although the wild or extremely feral male buffaloes compete with domestic male buffaloes to breed with domestic female buffaloes, it is very rarely that domestic male buffaloes gain access to female wild or feral buffaloes. This is because male wild water buffaloes secure their breeding territories more aggressively than domestic buffaloes. Hence the chances of wild genes to continue to propagate without getting mixed with the domestic water buffalo is greater.

Not infrequently, a wild bull will quit the jungle and take over a herd of domesticated buffaloes, driving away the owners and keeping the herd for itself. At other times, villagers will tie up their cow buffaloes, when in oestrus in the jungle in order to have them mated with a wild bull, believing that the strain is thereby improved (Phillips 1935).

There are no proper records or information on outbreaks of disease among wild buffaloes in Sri Lanka. Unconfirmed records state that Foot and Mouth Disease, Rinderpest, Haemorrhagic Septicemia outbreaks have occurred on several occasions at these parks. In 1994, a Haemorrhagic Septicemia outbreak was recorded in the Udawalawe National Park causing some elephant mortality. A recent survey has found the incidence of brucellosis among domestic water buffaloes, that graze within the Udawalawe National Park (Wijewardana *et al.*, unpublished).

Surveys have indicated that the wild buffaloes may serve as a reservoir of the Foot and Mouth disease viruses (Fernando, 1980). Though no proper investigation was carried out, it is believed

that diseases such as brucellosis, leptospirosis, parasitic diseases etc. exist and spread to domestic to wild and vice versa.

According to the preliminary survey (Table 1), the number of wild /feral buffalo is considerably low compared to domestic grazers. It is evident that effective seasonal breeding and the absence of any predators have contributed to maintain the wild buffalo population unchanged. Predators such as the Leopard (*Panthera pardus*), Crocodiles (*Crocodylus porosus* and *Crocodylus palustris*) and Jackal (*Canis aureus*), and drought conditions are the known major mortality factors. Removal of a certain number of buffaloes by the farmers for draught, and illegal poaching may also contribute to the control of wild buffalo population. It is believed that in the case as calf mortality, factors like parasitism are the major causes.

Therefore, the presence of a comparatively lesser and constant number of feral/wild water buffalo is not a problem in park management and they can be considered as a part of the ecosystem. At the same time, it is obvious that domestic water buffaloes do contribute to the present hazards of these parks. Thus elimination or at least a reduction in domestic water buffalo numbers in National Parks is essential to prevent habitat degradation and genetic contamination of wild water buffaloes.

The Fauna and Flora protection ordinance of Sri Lanka has given the authority to DWLC to remove or cull the domestic water buffalo population in National Parks. Under this authority, DWLC has taken action to capture and remove domestic water buffaloes on several occasions but they have failed due to poor planning and techniques used.

Considering the numbers of buffaloes and their offspring, they can be considered as a national resource. Thus, there should be a scheme to allow buffalo owners to keep or remove buffaloes in parks. The DWLC, the Department of Animal Production and Health and interested Non Governmental Organizations should collaborate to give effect to the solution of this problem. The implementation of eco-development activities in affected villages is the major suggestion in this direction. Under the national breed improvement program, extension program, fodder production program, milk handling and marketing programs, alternative job opportunities can be created in villages adjoining the national parks.

With the ongoing eco-development program, the domestic water buffaloes should be stopped from entering parks for grazing and buffalo farmers should be allowed to remove semi feral buffaloes. As an alternative, water buffalo should be removed by capturing, using chemical immobilization, machines and manpower or by trapping, to effectively keep the population of semi and domestic buffaloes out of parks. If however there is still an excess of feral water buffalo, with increasing population, young feral buffaloes should be removed completely or a selected age groups such as heifers should be removed as a population control strategy.

Conclusion

Domestic and semi-feral water buffaloes pose a major habitat threat to National Parks. It is not possible to achieve management goals in these parks without eliminating the excess buffaloes. Further research studies need to be carried out to focus on morphometrics, population statistics, cytogenetics, health, habitat enrichment and the carrying capacity of wild life in each national park. The following topics for investigation are suggested in this preliminary study.

- There is adequate evidence to believe that the buffalo population of National Parks has been contaminated with feral and domestic stocks. However, in the absence of any previous studies it is difficult to make a reliable assessment of the intensity of the problem. Therefore, it is important to develop a classification system based on morphometrics of these animals.

- This is a need to establish a complete data base and reliable scientific census of water buffaloes in National Parks.
- A comprehensive study of cytogenesis of water buffaloes and evaluation of their biodiversity value is needed.
- A study on the incidence of microbial and parasitic diseases.
- Habitat enrichment programmes, which can be implemented on National Parks to mitigate food competition of buffaloes with other herbivores.
- Establishment of the carrying capacity of wild buffaloes in National Parks.

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A HISTORICAL REVIEW OF THE USE AND MANAGEMENT OF THE WATER BUFFALO IN SRI LANKA

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Abstract: Sri Lankan water buffaloes (*Bubalus bubalis*) are of two types, wild or feral and domesticated. They had been introduced to Sri Lanka as a domesticated animal in 6th century BC with the migration of Aryans from India. Some available evidence confirms that semi-pastoral tribes raised them for agricultural and dairy purposes. The wild buffalo is a relative of the Indian wild buffalo (*B. arnee*) and some claim that they are feral populations of the domestic animals. Others have categorized this wild species as a separate sub-species called *B. bubalis migona*. However, there are distinct phenotypic differences present in both the domestic and wild species. Based on the phenotypic characters and activity, the domestic species can be grouped into "Beravā", "Ūru", "Gōṇa" and "Āth". The archeological excavations based on fossiliferous evidence suggest that this species was in the island in the present dry and wet zones even during the neolithic prehistoric era. The Sri Lankan water buffalo played a significant role in the ancient traditional culture. Many rock inscriptions dating back to 5th century AD reveal that ancient kings and noblemen offered herds of buffaloes and herdsmen to the Buddhist temples. During the 16th, 17th, and 18th centuries, the Kandyan kingdom had their own herds of buffaloes. In many ancient "village-tank systems" such as "purāṇa villages", keeping large herds of buffaloes was a common practice. These herds were known as "pattiya" and the owner and the herdsman were called "gosamika" and "gopalaka", respectively. As a result, the social status in the society identified by titles, such as "patti vidane" "nilamakkara pattiya" and "patikura", and even castes such as "patti" and "gopalukula" were evolved as sub-castes of "govikula" in the 16th century. Buffaloes were also used for many other purposes in the society, such as for ploughing and puddling of "paddy soils", puddling of clay for brick making and pottery. Buffalo skin was used as "canopy" or "viyana", bones and horns for making combs and handles of tools, and hair and bones as materials for "kamath rituals". "Pasgorasa" were the main food products obtained from buffalo. Evidence indicates that in the 1st century, beef consumption existed in the ancient society, although later, the eating of beef was considered unethical. Stalking buffalo or "dhada migona" was commonly used in the ancient society until the colonial era for hunting of game animals. Buffalo fighting or "migon pora" was a popular traditional sport during the era of the Kandyan kingdom. Many Buddhist scholars during 5th century have documented the raising and management practices of buffaloes in "Pali". The buffaloes should be grazed in one location only once in 5 - 7 days. When leading the herd to a water source, the pregnant cows, weak and sick animals and the calves should be in the fore front of the herd to avoid competition from the strong. Once the herd is returned from grazing the thorns in the skin, insect eggs and maggots should be removed and the wounds should be cleaned and bandaged with processed tree barks or "sumbulu". The shed and the surroundings should be kept clean especially during the rainy season. The leader of the herd or the "goparinayaka" should be fed and looked after well. In the Tamil text "thesavalamai", many rules and regulations are given on hiring of buffalo for land preparation. Today the books such as "goratnaya", "gavasiddisaraya" and "gavavedapotha" which address the traditional treatment methods for cattle and buffaloes have been derived from the ancient traditional knowledge.

Keywords: Historical aspects, wild buffalo, domestic buffalo, feral, traditional systems.

Introduction

Buffalo (*Bubalus bubalis*) is commonly known as the "beast of burden" in the tropical Asian region. The term buffalo is commonly used in the vernacular to refer to a person with an idiotic character or nature, although the real buffalo is not as idiotic as people think. Based on the behavioural characteristics of the buffalo, Cockrill (1976) made the following statement to describe the genesis of this beast; "After Noah had got all the animals aboard, he was left with a job lot - a sort of crook collection, he could not pair with anything. There was a pig, and a sheep, an old horse and a dog. He put them all into a big basket and shook it up for ten minutes and out came a pair of buffaloes. See! They like to wallow like pigs, they herd tightly as sheep, not like cattle they are as much a servant as the horse and are faithful as the dog".

Buffaloes play a vital role in the Sri Lankan agriculture, culture and to a lesser extent in other industries. History records that the buffalo kept the rural agricultural society together, through many group or community based involvements, such as the "*aththam*" system and the exchanging and sharing of this beast in agriculture based activities. Even in present day agriculture, they play a very prominent role as a source of farm power. They are not as "dumb" as one thinks, but is very intelligent and can be looked upon as the closest and most beneficial companion that our ancestors had, when this country was called the "granary of the east". One could imagine the contribution they made during that era to bring the country up to that level. This beast has not only assisted in bringing this country towards prosperity in the past, but will also continue to do so even today. Therefore, it is worthwhile to investigate the historical aspect of this beast of burden, the buffalo.

Origin

Cattle and buffaloes were part and parcel of the ancient agrarian system of Sri Lanka. This companionship dates back many centuries. Many of the prehistoric evidence available support this statement. However, no such evidence exists with regard to the goat and sheep, to establish that they were domesticated during, and lived in association with man in the early civilization (Geiger, 1960).

There are two types of Sri Lankan buffaloes, wild and domesticated. There is another group called "feral", the animals which were domesticated and later moved into the wild habitat. The Sri Lankan wild buffalo is different from the Indian wild buffalo. According to Deraniyagala (1953), the Indian wild buffalo is called "*Bubalis arnee*" whereas the Sri Lanka wild buffalo is called "*Bubalus bubalis*". The domestic buffalo is also called *B. bubalis*.

The wild species of buffalo in Sri Lanka is not as heavy as the Indian type, and has a small body size with short horns curving towards at the tip (Phillips, 1936). There are many arguments to support that the Sri Lankan wild buffalo is feral. However, Ellerman and Morrison (1966) dismiss this opinion. Since there was no evidence to endorse that the Sri Lankan wild buffalo (*B. Bubalis*) is a descendant of the Indian wild buffalo (*B. arnee*), Deraniyagala (1959) considered it as a separate sub-species and named it "*B. Bubalis migona*". He also described certain special phenotypic characteristics. According to him, the Sri Lankan wild buffalo is larger and stands higher in legs, with a coat of reddish brown hair. The horns are stronger, larger and more erect with their tips curving more forward than in the domestic animal and, shorter than in the Indian wild type. The spine is raised into a prominent hairy ridge at the withers and the head is more hairy. The neck is round and stronger. The calves of the wild type are darker in colour than the domestic type. These characteristics are in accordance with characteristics of the specimen head No. 783 of a wild buffalo kept at the Colombo Museum.

In contrast to this, Janeja (1958) reported that the Indian buffalo (*B. Bubalis*) is closely related to the Sri Lankan wild buffalo found in the Southern and Northern parts of the island. Robert Knox, in his book titled "A Historic Relation of Ceylon" mentioned that Sri Lankan buffalo was also known as "*Gavara*" by the local people. However, this is a misinterpretation, and it is worthy to mention here that *Gavara* is an entirely different species of ruminant (*Bos gaurus*). Phenotypically *Gavara* is closely similar to a cross between cattle and the buffalo, than the buffalo. This species existed on Sri Lankan soils until the late 19th century AD. Presently, a well preserved head can be seen at the Hill Club Hotel, Nuwara Eliya. The Sri Lankan species of *Gavara* has been named by Deraniyagala as "*Bos gaurus sinhalayus*".

About a century ago, the wild buffalo populations were in abundance in the low country forests. Subsequently, most of them became interbred with the domestic types. Therefore, it is doubtful whether the two types domestic and wild are entirely two different types or the wild type is a result of the domestic type becoming feral or, the domestic type being the result of domestication

of the wild type. Therefore, it is worthwhile to investigate whether both these types are the same or not and also their origin.

Eisenburg and McKay (1970) expressed a strong opinion that the Sri Lankan water buffalo is indeed a Pleistocene form and its introduction to Sri Lanka during historical times have to be revised. Sri Lankan buffalo can be classified as follows;

Order:	<i>Ungulata</i>
Sub order:	<i>Artiodactyla</i>
Section:	<i>Pecora</i>
Family:	<i>Bovidae</i>
Species:	<i>Bubalus bubalis bubalis</i> (wild species) <i>Bubalus bubalis</i> (domestic species)

They have also been classified as:

<i>Bos bubalis</i>	Linnaeus (1766)
<i>Bubalus bufelus</i>	Kelaart (1852)
<i>Bos bubalis</i>	Blanford (1891)

Fossils excavated from Ratnapura gem pits at a depth of 6 - 30 ft clearly demonstrated the presence of buffaloes in Sri Lanka in the prehistoric times. In addition to their presence in the wet regions, they were also abundant in the dry zone. All these fossil evidences were found during the archeological excavations either accidentally or otherwise (Deraniyagala, 1953). It may be possible that the semi-pastoral tribes living in the island may have domesticated buffaloes and cattle for agricultural and dairy purposes as in India (Allchin, 1962). This opinion is not easy to rule out, because in the history of Sri Lanka the use of buffaloes for draught and dairy purposes were clearly recorded in the ancient chronicles such as "*Mahavamsa*". It may be that early settlers who migrated from India during the 6th century BC, vanquished the native tribes and colonized the dry zone. They were from an agricultural based civilization and must have domesticated the buffalo and cattle for their agricultural practices (Siriweera, 1982).

Rouse (1970) bears a different viewpoint on the Sri Lankan buffalo. He believes that the Sri Lankan buffalo is a swamp type and possibly the early Sinhalese (Aryans) who migrated to Sri Lanka from Northern India during 6th century BC, introduced them from India to the island. Records in the *Mahavamsa* chronicles suggest that cattle and buffalo populations increased during the 4th century BC. However, during the 5th century BC cattle and buffalo keeping were recognized as a symbol of high social status. Evidence exist in the *Mahavamsa* to confirm the presence of large herds of cattle and buffaloes in the villages of "*Dvaramandala*" and "*Deegavapi*" in the southern parts of the dry zone (*Mahavamsa*). The present day evidence testify to this, since this area is basically an agricultural region.

Mediaeval Sinhala veterinary works recognized four types of buffaloes in Sri Lanka. This categorization is based purely on the phenotypic characteristics and activity or both. They have classified Sri Lankan buffaloes into the following four groups;

<i>Berava</i>	=	Black and active
<i>Uru</i>	=	Pig like, carries its head low and legs short
<i>Gôna</i>	=	Slender legs, head high and colour similar to sambur
<i>Ath</i>	=	Slow, elephant like breed (Deraniyagala, 1959).

This clearly indicates that even within a single species, some subspecies could exist.

Culture

Ancient Sri Lankan culture and society were closely linked with the buffalo and cattle, mainly because of the ancient agrarian civilization. Farm power was mainly derived from buffalo and no historic evidence is present in support of the use of the horse, the donkey or the elephants. The major crop cultivated was rice and according to the management practices and the nature of soil texture of paddies, the most suitable animal was the buffalo. Considering the observations made by Robert Knox regarding the worthiness of the paddy farmer even for kingship, one can imagine the level of royal patronage offered to this noble profession. If the buffalo was part of this recognition, equally similar royal patronage would have been paid to the buffalo, too. Traditional paddy cultivation was linked with many spiritual, cultural and customary activities

The buffalo was also reared by the Muslim community, because buffalo ghee was an important ingredient in their traditional cooking. Ghee is a product of buffalo milk. The qualities of the buffalo as a working animal were also better appreciated by those who follow the teachings of Islam, who regard patience as a virtue and accept that "in whose property there is a due portion for those who ask and those who are prevented from asking (also all the dumb animals)" (Holy Koran).

After the 16th century AD, both cattle and buffalo raising was accepted as a noble profession, and one who keeps cattle and buffaloes was considered to be a high class person in society. Eventually, in the Sinhala cast system two sub-classes emerged as "*Patti*" and "*Gopalu*" from the noble class of "*Govi*" (*Mahavamsa*). Other ancient chronicles such as "*Chulavamsa*" "*Rajaratnakaraya*" provide sufficient evidence on the offering of buffaloes and cattle to temples and viharas.

According to the rock inscriptions found in Jaffna, during the 11th century AD 15 buffaloes were offered to the *Velgam* vihara by a Tamil national to obtain ghee for the lighting of the lamps in the vihara (*Epigraphia Tamilica*, 1971). Epigraphical evidence at *Galapatha* vihara, near Bentota reveals that offerings were made for the protection of buffaloes and herdsmen (*Epigraphia Zeylanica*, 1904). During the 14th century AD, a commander by the name Senadhilankara offered 400 buffaloes to the *Lankathilaka* vihara. This was engraved in a stone pillar at *Hevavissa* Korale in Kurunegala district (Paranavithana, 1960a). In addition to this, the king also had offered the services of herdsmen to the vihara to manage the herds (Paranavithana, 1960b).

It was a traditional custom during the period of Sinhala rulers that when a temple or a vihara owned a large herd of cattle or buffaloes, the king provided services to manage the herd by providing the herdsmen. These herdsmen bore a high noble status in the society and were honoured with respectful positions affiliated to their name such as "*Pattividhane*" or "*Nilamakkara*". In the royal palace, there was an official position called "*Pattividhane Nilame*" who was the chief of the milkmen and buttermen (Perera, 1916). These positions were so respected and accepted by the then society, that they continue to use these ancestral names to indicate their descent from honoured ancestors.

The owner of a large personal herd was called "*Gambaraya*". He was accepted as a member of the high society not only for his wealth but also for the nobility. The cattle or buffaloes that belonged to a vihara were treated as a royal property and they were not permitted to be used for agricultural purposes or any other use other than keeping for milk and *pasgorasa*. The regulations were such that they could not be even used for "*Rajakariya*".

Uses

Buffaloes had been used from the inception of the agrarian civilization of Sri Lanka. In wetland agriculture, buffaloes are preferred to cattle due to many reasons. In rice cultivation they were used from the initial land preparation to the final threshing. In the 13th century AD documents

such as "*Pujawaliya*" and "*Soddharmaratnawaliya*" mention is made of the use of the buffalo drawn plough for land preparation in paddy cultivation (Siriweera, 1993). According to the epigraphical evidence, in the 9th and 10th centuries AD buffaloes had been used for draught equally with cattle (*Epigraphia Zeylanica* 1904).

Trained buffaloes were also used for hunting of other animal species. They were also used to capture the wild or feral buffaloes for domestication (Story, 1907). Hunting deer and wild boar with the stalking buffalo or "*Dadha migon*" was very popular in the past in *Pasdun Korale*, east and south of Kalutara (Tennent, 1861). During the British rule, hunting of wild buffaloes for game was a very popular sport, which was only second to hunting elephants. The hunted animal heads were preserved and hung on walls as trophies. Such trophies can still be seen in estate bungalows and in the Hill Club Hotel at Nuwara Eliya. The value of the trophy was measured by the length and the span between the horns (Story, 1907). The skin of the buffalo was a very valuable item. This was used to make canopies or "*Viyana*" and also the drums or tomtoms. Horns and bones were used in making ornaments, combs and tool handles. The bones and hair were used for spiritual activities in the "*Kamath*" or threshing field traditions. Urine was an important ingredient in the traditional medicinal system (*Dharmapradeepika*, 1927).

During the battle between King Elara and King Dutugemunu, molten metal was poured on the back of King Dutugemunu's royal elephant. After veterinary treatment, the elephant was sent back to the victorious battle by applying one hundred layers of buffalo skin on the back of the elephant. Well processed buffalo skins were also used to make "*Paliha*" (shield) and "*Sum Salta*" (leather vests) (*Chulavamsa*, 1929).

"*Magasalakunu*" a text dating back to the 15th century AD mentions a "*migon aramba*" at Kandy where traditionally the "*Pora migon*" (fighting buffaloes) or "*Dadha migon*" (stalking buffaloes) were kept. D'Oyly (1810) also made mention of a migon aramba near *Malvattu Vihara*. According to the records the best pora migon came from "*Sathara Korale* (four korales) and the large and heavy bull from "*Vellassa*" of Badulla District. Deraniyagala (1959) gives a detailed description of the required phenotypic characteristics and how the animals were selected trained, and how the fights were conducted according to the rules of the game. Near Kadugannawa regular fights were held during the paddy harvesting season until recently.

"*Pasgorasa*" (in Pali *Pancagorasa*), or five tastes of excellence are very valuable food items in both royal and ordinary menus. These products were made of milk offered or used only on royal occasions. Some of these were essentially made of buffalo milk. These *pasgorasa* consist of "*Kiri*" (milk), "*Dee kiri*" (curd), "*Yodhaya*" (cream), "*Gitel*" (ghee) and "*Vendaru*" (butter) (Ariyapala, 1956). Since ancient times the southern and eastern regions of Sri Lanka had earned a name for its popular curd. During periods of Sinhalese rulers, there were herds (*patti*) maintained exclusively to supply curd to the royal diners. The person in charge of the operation had an official position in the palace called "*Pattividhane Nilame*".

Some fossil evidence suggest that the early inhabitants of this island consumed beef and yet there is no ground to assume that cattle or buffaloes were reared for meat. According to the animal bones and other artifacts found in the Anuradhapura "*Gedige*", the period was datable to be between 400th century BC to 20th century AD (Anon, 1972). However, during the Anuradhapura period, when there was a marked increase in Hindu influence on Sinhala culture, beef eating was considered unclean by the elite society and even a "taboo" was imposed on eating beef (Siriweera, 1982).

Very little evidence exists to suggest that buffaloes were ever used in the transport activities. However, cattle have been extensively used in transport of people as well as goods. In the past there was a special type of a cattle called "*Gal gon*" used for this purpose, which are especially used to draw carts or "*gal*". This herd was known as "*gal gon panthiya*". In addition to *gal gon*,

goods have been transported on the back or alongside of the animals. These were referred to as pack animals or "*Thavalama*". The animals are referred to as "*goni gon*" (Siriweera, 1982).

During the construction of the dams of the ancient lakes, compaction of the soil was needed. Even though the evidence is scanty or absent, many believe that cattle and buffaloes were used for this purpose and not elephants. Buffaloes were also used to mix and season the mud in pottery and brick industry in the Kelaniya region (Deraniyagala, 1959). This shows the many types and the enormous quantity of work that had been performed by the buffalo since ancient periods.

Management

Management is one of the important aspects of buffalo rearing. As mentioned before, owning or rearing buffaloes was considered a noble status symbol in the society. During the 5th century AD and other periods, many Buddhist scholars such as "*Buddhaghosa*" wrote many Pali texts on cattle and buffalo rearing. "*Samanthapasadika*" is one such text and gives many guidelines under the "*Vinaya*" (discipline) on domestic cattle and buffalo management.

According to the text, breaching a dam of a reservoir is a serious and punishable offence. Any person who drives his cattle over a dam or a bund of a reservoir was also considered an offender and if any damage was caused to the dam, the owner had to pay compensation. In another Pali text "*Papannasudhani*" or "*Majjhimanikayatthahata*", much more guidelines had been detailed. According to this text, the system of management is based on the size of the herd. If the herd is small, the entire labour is borne by the family labour. The large herds are known as "*Patti*". The owner of a *patti* was called "*Gosamika*" and the herdsman "*Gopalaka*". Buffalo and cattle keepers also believe in a deity called "*Gopalla*" who they believe looked after the well being of the animals by blessing them and protecting them from evil spirits and influences. To satisfy the deity and thank him for the services rendered, the cattle keepers perform a "*Pooja*" annually. During the *pooja* they make "*Kannolau*" (prayer) and "*Yadhika*" (offerings).

According to the *Papannasudhani*, the herdsman or the *gopalaka* has certain duties to perform. He should be aware of the number of animals in his herd by colour or by any other body marking. To identify animals, they will be branded (moxibustion) or "*Hanwadu*" with a red hot iron. Branding, in addition to its use as an identification, also indicate the social status of the owner. Generally, tridents (*thrishulaya*) and arrows (*eethalaya*) were the common signs used in branding. Branding was also used as a means of treatment of certain illness (e.g. gout and paralysis). The animal sheds should be kept well cleaned and fumigated to prevent the breeding of pests and insects. Many instructions have been detailed on how to clean and dress an infected wound. These will be discussed under health.

The leader of the herd or the stud bull was called "*Goparinaika*" and the animal should be cared for well. According to "*Ummagga Jathikaya*" (1957), to maintain the body condition and the vigour of the *Goparinaika*, it should be fed with rice porridge and gingelly oil cake. In addition it also should be groomed and massaged every day. Grazing in the same location can affect both the forage and the animal. Therefore, the text emphasises that a location should not be grazed for more than one day and to return to the same location only after 5 -7 days. This will allow the forage to regrow and provide new, lush and quality forage for the animals for better nourishment. This practice is very appropriate and similar to the present day "rotational grazing system". Provision of water to the herd is another important aspect described in the text, *Papannasudhani*. When leading the herd to water sources especially during dry seasons, when water is scarce, calves, pregnant cows and weak animals were allowed to lead first followed by the stronger animals to prevent any competition. As the text explains, if the stronger animals go first and disturb the water, the calves and productive animals will not drink the muddy water and not only can this reduce their feed intake and lower the production, it can even make the animal sick. It also stipulated the manner in which a cow should be milked in order to maximize the milk yield and obtain clean hygienic milk. The authors had not forgotten the nourishment of the calf too.

According to the text, during milking one quarter of the udder should be completely left to the calf with the residual milk of the rest of the quarters. Any person violating this rule was subjected to severe punishment. 12th century AD texts such as "*Rasavahini*" also makes mention of the herdsmen or *gopalaka*.

In another ancient Tamil text of "*Thesavalamai*" (1707), clear guidelines were laid down in the form of rules and regulations as procedures to follow during hiring and lending of buffaloes for land preparation purposes. These were to be abided by both the lender and the taker. An "*Ande*" or leasing system was also present during the 19th century AD. For the first time in history, trading of the buffalo for money was recorded in the 16th century AD during the later part of the Kotte Kingdom. During that period the price of a buffalo was 8-12 gold ingots (*kahavamu* = 280 grain gold coin or the weight in gold of 40 *olinda* seeds-*Abrus precatorius*). These historic facts very well demonstrate how much attention was given to the ancient management system of cattle and buffalo in the Sri Lankan society, culture and agriculture.

Health

Sri Lankans have a recorded history of traditional treatment systems and veterinary care. The ancient King Ravana had his own animal hospital to treat animals, whereas King Buddhadasa (362 - 409 AD.) himself treated animals. Many other kings had their own veterinarians to look after their "*Athpanthiya*", "*Aspanthiya*", "*Gavapattiya*" and even "*Kukkan maduwa*" (kennels). This suggests the existence of a strong veterinary and surgery system in Sri Lanka. According to *Papannasudhani*, the prime duty of the herdsman was to look after the general health and hygiene of the herd and the stalls. Any condition of ill health due to irresponsible management or ignorance was subjected to severe punishment, as such behaviour would have destroyed not only his own herd but the herds others as well. The text strictly emphasises that a sagacious herdsman would treat any wound caused by thorns or puncture, which should be treated according to the severity of the injuries. At first, all the thorns that are stuck to the skin should be carefully removed. Then the fly eggs and maggots should be completely removed, cleaned and medicine containing margosa oil applied and thereafter bandaged with processed tree barks or "*Ruk Sumbulu*", as animals with infected wounds will not only suffer themselves, but also infect the other animals in the herd and other herds as well during open grazing.

Branding or moxibustion is another common method of treatment for many ailments. When used as a treatment, many different and complicated symbols are used. Such symbols are called "*Sutra*", the branding marks are called "*Yanthras*", the words chanted during branding are called "*Mantras*". The locations for branding and the symbols depend on the type of ailment. Other ancient and common treatment methods includes "*Kem*", "*Manthram*", "*Beheth gediya*" (medicinal ball), "*Kashaya*" (decoction), "*Nasna*" (inhalers), "*Pattu*" (pastes), "*Guli* and "*Kalka*" (boluses), "*Thila*" (oils) and "*Arishta* and "*Asava*" (syrops and sprits). These medicines are mostly herbal based and must have been derived from the traditional medicinal systems, *Ayurvedha* or *Siddha* system or combination thereof. Most of these traditional cattle and buffalo treatments are gradually disappearing with the demise of the older generations. Valuable ola documents are available but are not made available for publication. Few published texts such as "*Gava veda potha*", "*Gorathmaya*", "*Gavasiddisaraya*" and few other "*Puskola poth*" (ola leaf documents) are rarely available.

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CHANGING ROLE OF THE WATER BUFFALO IN THE SRI LANKAN AGRARIAN ECONOMY

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Abstract: Water buffalo has been an integral component of crop-based agricultural production systems in Sri Lanka for centuries. The total buffalo population, which was estimated to be 410,418 in 1946, increased to 727,700 in 1999, while the number of smallholdings carrying buffaloes decreased from 99487 in 1946 to 50,000 in 1995. Along with these changes, the traditional role of buffaloes has also changed over the last 5 decades. The traditional role of buffalo has been its use on paddy land for ploughing, puddling and levelling before planting, and threshing after the harvest of paddy. Besides this, they were used for harrowing of dry land for cultivation and clay mixing. The extent of the paddy acreage prepared by animal power was 47.6% in 1980, but decreased to 20.3% in 1999. In most parts of the country, the buffalo has been replaced by the tractor, which was introduced into the country in the 1940s. While the use of the buffalo for draught has been on the decline, the use of buffaloes for milk has increased gradually specially in the peri-urban areas. During the 1960 - 1999 period, buffalo milk production increased from 28.5 million litres per year to 79.85 million litres per year. During this period, the amount of buffalo milk collected by the formal market increased from 2 million litres to 4 million litres, while the production of dairy products from buffalo milk increasing by around 40%. This was the result of the introduction of improved breeds and cross breeding programmes, in order to improve the productivity of the animals. This has resulted in the indigenous buffalo population decreasing to around 70% from 95% and the improved buffalo population increasing to 30% from 5% respectively, since 1960. Although, the buffalo has been used for meat for a long period, a government directive in late 1970s imposed a total ban on the slaughter of buffaloes for meat as a measure to prevent the decline of the buffalo population. However, unofficial estimates suggest that, the number of buffaloes slaughtered illegally has been on the increase. These estimates indicate that approximately 1/3 of the beef supplied to the market is derived from buffaloes, despite the existence of the ban on slaughter of buffaloes. In conclusion, the role of the water buffalo has become more important than before and its traditional role as a draught animal has changed to a multipurpose role as a source of milk, meat and draught.

Keywords: Population distribution, rearing systems, changing role.

The Buffalo of Sri Lanka and its Origin

Though the indigenous buffalo of Sri Lanka is classified as a swamp buffalo, it possesses 50 diploid chromosomes (Bongso *et al.*, 1978) like the river buffaloes. This has given rise to the view that the indigenous buffaloes of Sri Lanka are descendents of the river type buffaloes, introduced into the island by immigrants from India during the 6th century BC. The fossilised remains of buffaloes recovered from the dry zone areas and gem mines in Ratnapura, suggest that during the prehistoric era both buffaloes and cattle roamed the island before the first millennium BC (Deraniyagala, 1953). The most plausible explanation as to how the indigenous swamp buffalo of Sri Lanka came to possess 50 diploid chromosomes may be that immigrants from India during the 6th century BC brought with them the river type of buffaloes found in India. These animals were crossbred with the domesticated indigenous swamp buffalo, which later became wild. The change in the karyotypes of the hybrids had been observed in offspring resulting from *inter-se* mating of F₁ from swamp buffaloes and river type dairy buffaloes of Indian origin in Thailand (Sabine, 1992).

The Role of the Buffalo in Ancient Sri Lanka

The Mahawansa states that during the reign of King Pandukabaya in the 3rd century BC, the existence of a Gopalu caste (caste to which herdsmen belong) in the Digavapiya area (Mahavamsa, 1912). There is evidence to suggest that buffaloes and cattle had become an integral

part of the agricultural economy during the first millennium AD. The Papancasudani dating back to the 5th century AD, lays down the regulations concerning the management of dairy herds (Woods and Kasongi, 1928). There are many historical references in the 9th and 10th Century AD stone inscriptions on buffaloes, cattle and dairy farming. Buffaloes and cattle were both used in agricultural activities such as ploughing, puddling, threshing, besides being used for the transport of goods and people and in the brick making industry (Ellawala, 1962). The hides were used for various purposes, horns to make combs and other artefacts and bones and manure were used as fertiliser.

From the second half of the 1st millennium BC to date, rice has continued to be the staple diet of the majority of Sri Lankans. The main thrust of the agriculture production system was directed towards the cultivation of rice. The buffalo, the main source of draught power in paddy cultivation, played an important role in the then Sri Lankan economy. Being a valuable source of draught power in the production of food, the ownership of buffaloes and cattle had an important status in the pre and post AD eras. As buffaloes and cattle belonged mainly to the rulers and temples, only a small number were owned by peasants. Edicts in stone inscriptions and in "Thombus" from the Portuguese era made it mandatory for villagers to supply buffaloes and cattle to cultivate the paddy fields owned by the king and temples, as well as for transport of produce, and to transport men and material for military purposes (Silva, 1995).

Milk was mainly processed into clarified butter, ghee and curd. These were often offered to monks as food, medicine, cooking oil and as fuel for lighting. Both buffaloes and cattle were not reared for meat after the advent of Buddhism to Sri Lanka. During the reign of King Bhatiya, eating buffalo and cattle meat was totally prohibited for those of the high castes (Ellawala, 1962). The high caste people who consumed beef were demoted to a low caste. The prohibition of beef eating also implied the prohibition of the slaughter of buffaloes and cattle. Though beef eating was prohibited, the consumption of meat of wild animals was not banned.

During the pre-colonial times, butter and ghee were the main commodities that were traded exclusively in Sri Lanka. Breeding of buffaloes for milk, butter and ghee was a traditional practice in ancient Sri Lanka and it was customary to pay part of the dues to the king in the form of butter and ghee, especially in Jaffna (Silva, 1995).

With frequent invasions from South India during the 11th century onwards and the consequent destruction of the irrigation system, paddy cultivation in the dry zone gradually declined and the use of the buffalo as a source of draught also declined, most of the animals becoming wild over the years. During the Portuguese and the Dutch era, the importance of the buffalo as a draught animal declined further due to the neglect of the paddy cultivation, as the foreign rulers were more interested in trade rather than developing indigenous agriculture. It was only during the British in the latter half of the 19th century that a revival of the use of the buffalo as a draught animal and revitalisation of rice cultivation took place.

Distribution of the Buffalo Population

Compared to cattle, buffaloes are not widely distributed across the island, but are concentrated in certain areas. The total buffalo population has been estimated to be 727,700 heads in 1999. The buffalo population density is high in the rice cultivation areas and in large tracts of jungle and scrub land where available (Figure 1). The population distribution of buffaloes shows that the highest distribution is in the dry and dry intermediate zones compared to the wet and wet intermediate zones. The districts of Kurunegala (19.6%), Anuradhapura (12.0%), Hambantota (8.4%), Ampara (6.9%), Polonnaruwa (5.6%), Batticaloa (7.6%) and Moneragala (4.7%) have comparatively high buffalo populations (Abeygunwardena and Abeygunwardena, 1998a).

The number of adult buffaloes per hectare of paddy land gives a clear indication of the availability of draught power per hectare of paddy land in the different districts. The districts of Colombo,

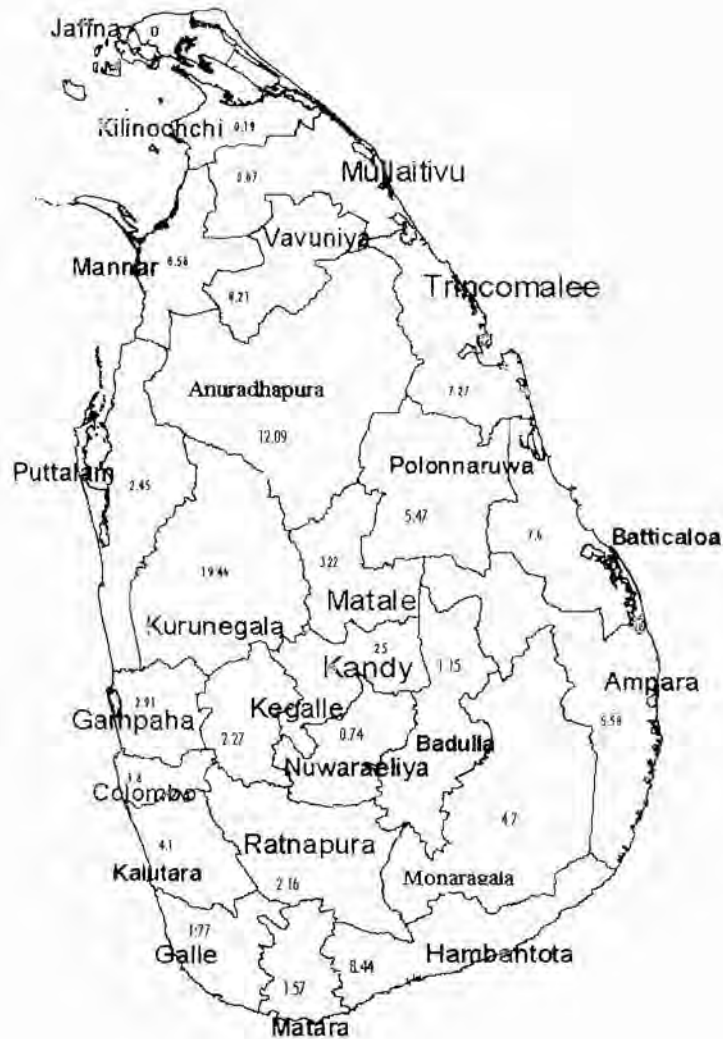


Figure 1. Distribution of the buffalo population in the different districts as a percentage of the total population 1999
Source: Department of Census and Statistics



Figure 2 .Number of buffaloes per hectare paddy land 1999
Source: Department of Census & Statistics

Gampaha, Trincomalee, Kalutara, Hambantota, Moneragala, Kegalle, Kurunegala and Anuradhapura have more than 1.2 adult buffaloes per hectare. The districts of Galle, Matara, Ampara, Ratnapura, Nuwara Eliya, Polonnaruwa, Vavuniya, Mullativu, Mannar and Kilinochchi have a lower buffalo density per hectare of paddy land (Figure 2).

A comparison of the population distribution of buffaloes in 1981 with that of 1997, indicates that there has been a decrease in the buffalo population in the wet, wet intermediate and dry intermediate agro-ecological zones. The percentage decrease in population is high in the wet intermediate zone (-33.2%) followed by the wet zone (-20.4%), the dry intermediate and dry zone (-15%). The overall decrease in the buffalo population in the whole island was -15.4% (Table 1). The reason for this is the high demand for land for commercial and residential purposes especially in the urban areas, which has resulted in the filling of paddy fields for these purposes. Increased mechanisation of paddy cultivation practices has also been a contributory factor. The average herd size in different ecological zones varies from 13.2 animals per herd in the wet zone and 34.4 animals per herd in the dry zone per farm (Table 2). A comparison of the population data of years 1985 and 1999 shows that the percentage of improved breeds has increased in all agro-climatic zones except in the wet zone, where the percentage of improved breeds has decreased by 5% (Table 3).

Buffalo Rearing Systems

The majority of the farmers in the Matara and Hambantota districts keep buffaloes with the main objective of milk production, whereas the buffalo farmers in Ampara and Batticaloa keep buffaloes with the dual objective of milk and draft power. In milking herds buffalo cows are milked only once daily and the milking is done in the morning, before the animals are sent out for grazing.

The different buffalo management systems have been influenced by differences in climate, cropping patterns, type of crops and the genetic composition of the animals maintained in different areas (Abeygunawardena and Abeygunawardena, 1998b). In the dry zone, buffaloes and cattle rearing under the extensive system has been a traditional practice. Buffaloes and cattle are grazed together in scrublands, tank bunds and fallow paddy fields and are usually paddocked at night. The farmers use the buffalo as a source of draught power, to complement their income from paddy cultivation, while some are milked the milk sold as fresh liquid milk or as curd. In this system the inputs are marginal, the main component being the family labour.

In the wet and wet intermediate zones, buffaloes are reared under the semi-intensive system as most of the land in these areas is used for intensive crop cultivation, restricting the availability of land for grazing. The animals are either tethered under plantation crops or allowed to graze on fallow paddy fields and on roadsides. The inputs needed are moderate and as in the extensive system, the income complements the farmer's income from cash crops.

The intensive system is practiced in the urban and peri-urban areas where there is a ready market for milk and milk products. Animals are kept in sheds and fed on cut fodder and agro-industrial by products or concentrates. Though the cost of inputs is high, the resulting additional income justifies the inputs. Most of the urban and peri-urban buffalo farmers who rear their animals under the intensive system, depend on dairying as their main income source.

Changing Role of the Water Buffalo

Traditionally, the buffalo has been known to be a more rugged animal than cattle. Compared to cattle, buffaloes have the ability to graze in wet and marginal land, as the relatively large rumen capacity and the presence of the rumen microflora enable them to digest low quality roughage. The apparent fibre digestibility coefficient is 5-8% higher than that in cattle and the buffalo consumes less dry matter/kg live weight than cattle (Tulloh, *et al.*, 1992). The stamina and the

ability to pull heavy loads under different soil conditions when compared to cattle makes the buffalo much more suitable than cattle for ploughing and puddling of rice fields specially under wetter conditions. The relatively large under surface of the hoofs when compared to cattle is an advantage when working in the clay soil. Another advantage is that there is no difference in the draught output between males, milking females and non-milking females. One buffalo can provide the draught power requirement to cultivate around 3 ha per season. One buffalo can plough 0.25 ha/8 hour working day when compared to cattle, where a bullock can plough only 0.2 ha/8 hour shift (Ryan, *et al.*, 1981).

Table 1. Trends in buffalo population in different agro- ecological zones

Zone	Number of animals		% Change
	1981	1997	
Wet-zone	155700	123900	-20.42
Wet-intermediate	98600	65800	-33.26
Dry-intermediate	289300	268600	-15.08
Dry zone	354700	301206	-15.08
Total	898300	759506	-15.45

Source: Department of Census & Statistics

Table 2. Average herd size and range in different agro-ecological zones

Zone	Av. Herd size (No. of animals/herd)		
	Average	Maximum	Minimum
Wet-zone	13.25	69	1
Wet-intermediate	25.025	242	1
Dry-intermediate	31.0	138	2
Dry zone	34.4	152	2
Overall	26.2	242	1

Source: de Silva *et al.*, (1985)

Table 3. Percentage of herds carrying improved breeds in the different agro-ecological zones

Zone	Percentage of buffalo holdings		
	1985 ¹	1999 ²	%Change
Wet-zone	26.5	24.2	-9
Wet-intermediate	16.8	26.0	+54
Dry-intermediate	31.8	38.0	+22
Dry zone	30.25	33.7	+11
Overall	26.3	30.4	+13

1. de Silva, *et al.*, (1985)

2. Ibrahim, *et al.*, (1999)

However, over the last few decades the role of the buffalo in Sri Lankan agrarian society has changed due to many reasons. The growth in the land ownership and the subsequent parcelling of existing paddy land due to the population growth and pressure on the limited available land are the causes of the continuous decline in the available land area per person for cultivation. In addition, in the context of the increasing diversion of land resources for non-agricultural uses, the only way to maintain farm incomes and maximise the utilization of available family labour and other resources is to intensify crop livestock integration, with maximum usage of the available biomass for the production of food.

In such a scenario, the buffalo plays a significant role in the sustainable crop-livestock integrated system, not only by providing draft power, but also at the same time in converting fibrous plant

material that have no other productive uses, to animal products which is convertible to cash.

Draught

The distribution of resources, mainly of labour, the availability of animals and tractors determine the relative importance of animal power. The majority of the farmers utilise mature buffaloes of either sex, except lactating cows and those in late pregnancy in cultivation work. A small percentage of farmers use only male animals for cultivation. The average age of the buffalo when they are first used for ploughing and levelling is 3.1 years. The animals to be used for draught are first used for puddling and threshing and later they are trained for ploughing. The approximate number of hours worked per animal in a day is 6 to 8 hours and the approximate number of days worked in a year is 35 to 52 days. The working life span of a buffalo is around 15 to 16 years. The calculations based on such data indicate that the total number of days worked during its working life span of a buffalo to be around 360 to 628 days (de Silva *et al.*, 1985).

%

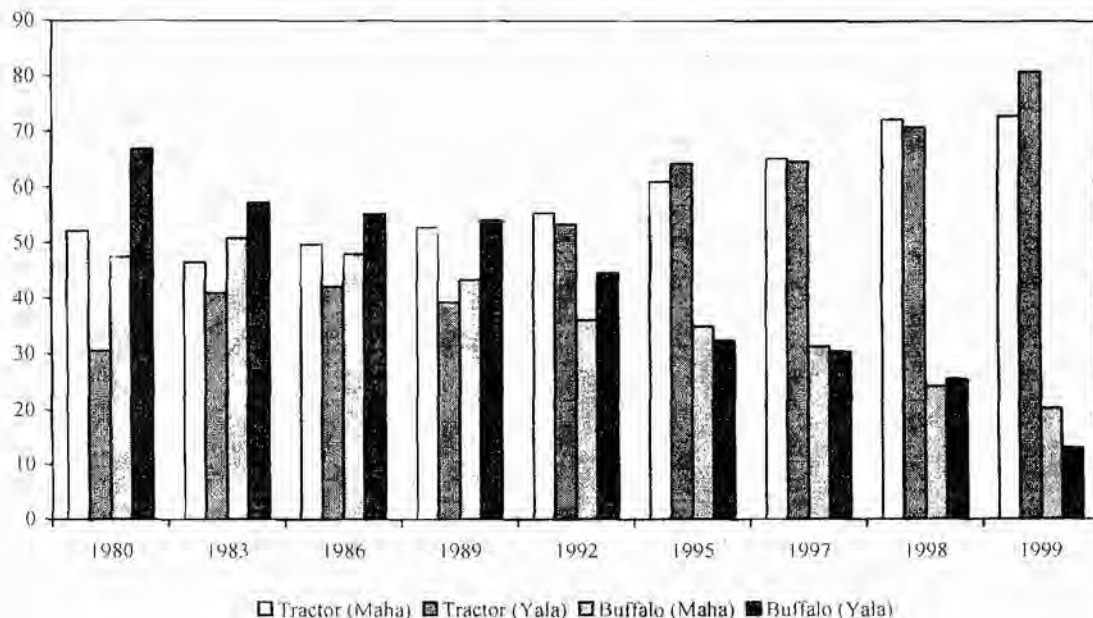


Figure 3. Trends in the use of mechanical and animal farm power in paddy cultivation during the Maha and Yala seasons from 1980 to 1999. (Source: Department of Census and Statistics)

The extent of the paddy acreage has been increasing during the last five decades from around 390,133 hectares in 1952 to 892,053 hectares in 1999, due to the rehabilitation and reconstruction of large and minor scale irrigation projects under the government's drive for self sufficiency in rice production. The dry zone accounted for 55.8% of the total 'aswedumized' acreage of paddy in the 1998/1999 Maha season, and carries 54% of the national herd. However, a large proportion of the animal power remains underutilised due to several reasons. The smaller land holdings and higher buffalo and labour densities per unit of paddy land in the wet zone accounts for the low use of tractors for ploughing and puddling in preference to animal power and labour. There was a brief revival in the use of the buffalo in paddy cultivation that occurred in early 1970s, due to the import restrictions on farm machinery (for paddy cultivation). In spite of the continuing increase in fuel prices and the consequent increase of the cost of ploughing, puddling and threshing of paddy by four wheel and two wheel tractors, within the last 20 years the extent of paddy land cultivated using mechanical draught power has continually increased and the use of buffalo in paddy cultivation has been on the decline. The extent of the paddy acreage prepared using animal power was 47.56% in 1980 but decreased to 20.3% in 1999. During the same period the acreage

of paddy land prepared using mechanical power has increased to 80% in the 1999 Maha season and to 72 % in the 1999 Yala season, respectively from 50% and 30% in 1980 (Figure 3).

Another factor for the declining use of animals for paddy cultivation has been the introduction of new varieties of rice which need a shorter time to ripen compared to the older varieties and the introduction of new cultivation and management techniques, which necessitate simultaneous cultivation of all land in a given area. The other factor is that compared to rain fed paddy cultivation, in irrigated paddy cultivation (both under major and minor irrigation systems), the water availability for cultivation is limited and is made available only in limited quantities and during a limited period. Under such a water distribution scheme, only 3.64 acre feet of water is released for paddy cultivation during the Maha season within a period of 4-4.5 months. In Yala, 5.39 acre feet of water is released within a period of 3-3.5 months. This compels the farmer to complete the task of land preparation during a very short period of time and in such a system animal power does not provide the required speed compared to mechanical power.

Milk

The relative importance of milk and curd production differs from district to district, with curd production dominating in Hambantota, Galle, Kalutara, Polonnaruwa, Batticaloa, and Anuradhapura districts, while the sale of liquid milk dominates in other districts (Horadagoda, 1998).

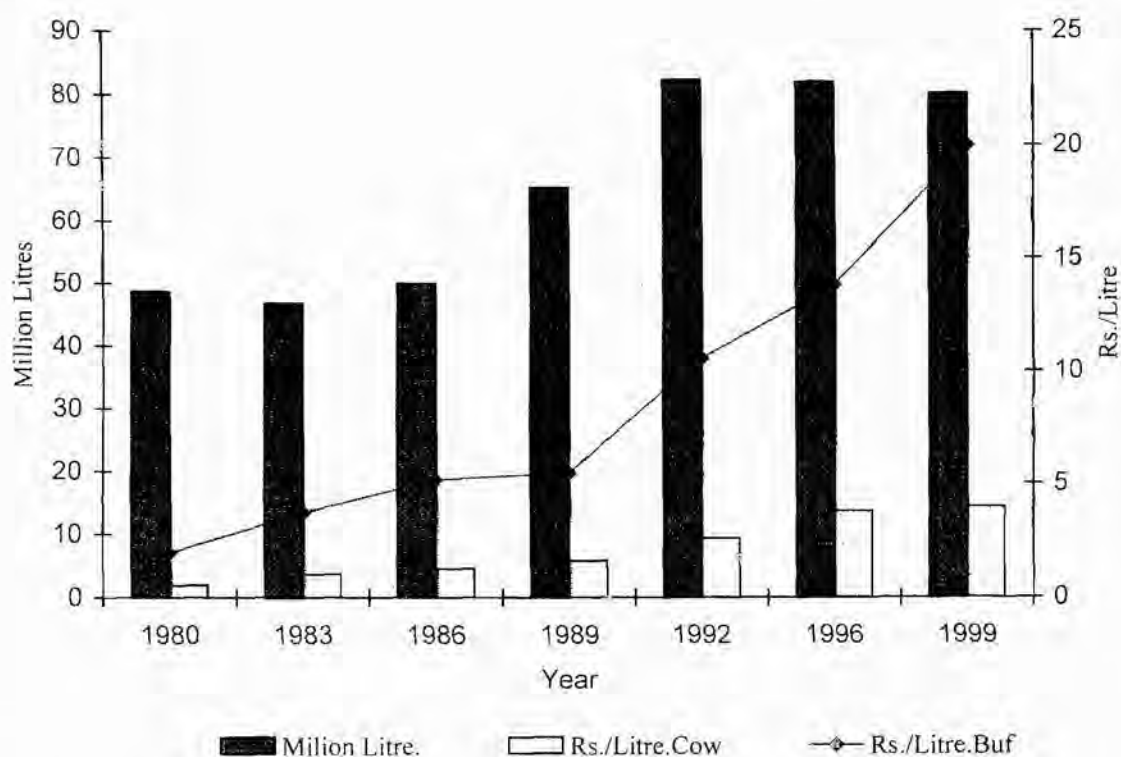


Figure 4. Trends in production and market price of buffalo milk 1980-1999

Source: Department of Census & Statistics

Buffalo milk is rich in energy and fat when compared to that of cow milk (buffalo 7.45% fat and 100 calories/g; cow milk 3.5% fat and 70 calories/g) and this offers several advantages over cows milk (Kon, 1972). Only a small number of farmers milk their buffalo cows through out the year, while the majority of the farmers milk their cows only during limited periods of 2 to 3 months

after calving. This is due to the fact that (1) there is a need to use the animal for draught, (2) the limited availability of fodder for grazing and (3) the inadequacy of milk for the calf. The yield per animal is 1.1 to 1.9 litres per day. The lactation length is 8 to 9 months in buffaloes used mainly for milking and around 2 to 3 months in buffaloes which are not used for milking. The proportion of herds that are milked is high in Trincomalee, Batticaloa, Polonnaruwa, Anuradhapura, Hambantota, Ampara, Ratnapura, Matara and Kalutara Districts.

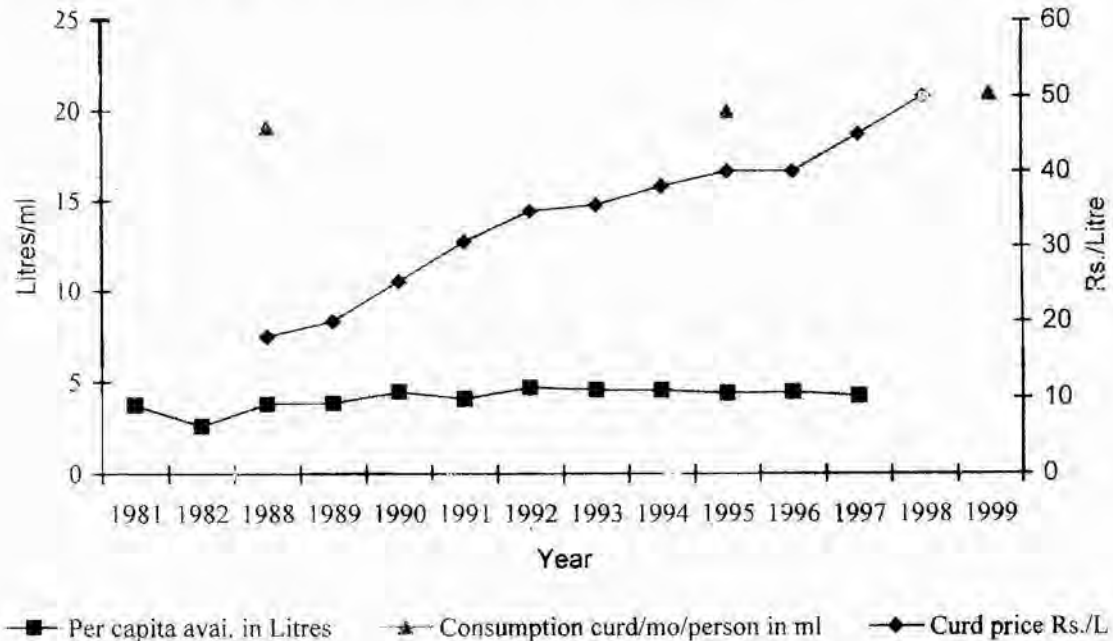


Figure 5. Trends in the availability, consumption and market prices of value added product, curd
Source: Statistical Abstracts (1999), Department of Census & Statistics, Central Bank (1999).

Most of the buffalo farmers who milk their animals do not sell the milk as fresh milk but process it into curd to obtain a higher price. The curd industry has existed as a traditional activity in the dry and dry intermediate zones to supply the urban areas with curd. However, during the recent past, the curd and yoghurt industry has developed in the peri-urban areas to cater to the developing market created by increasing urbanization and high income levels. The peri-urban buffalo farmers rear crossbred buffaloes of the Murrah and Nili Ravi types, and the animals are stall fed with concentrates in some instances. Such animals give a daily yield of between 4-5 litres per day reaching around 7 litres at peak lactation, with a lactation length of 8-9 months, when compared to the low yield (1-2 l/day) and the short lactation (6-7 months) of the indigenous buffalo. As shown in Figure 4, during the period 1960 - 1999, buffalo milk production increased from 28.5 million litres to 79.85 million litres per year (Department of Census and Statistics, 1999). During this period of nearly forty years, the amount of buffalo milk collected by the formal market increased from 2 million litres to 4 million litres, with the production of dairy products from buffalo milk increasing by around 40%. This was due to two factors, namely genetic improvement of the productivity of animals and high market price for the produce (Figure 4). The daily per capita availability of buffalo milk increased from 2.8 litres per day to 4.44 litres per day during the past 20 years (1982 to 1999). During the same period the per capita consumption of (Central Bank, 1999) curd per month increased from 17 to 21 ml, the price of a litre of curd increasing from Rs.8.00 per litre to Rs.50.00 per litre (Figure 5).

Meat

Buffalo meat is high in quality compared to beef from cattle as it contains 41% less cholesterol and less calories (Ranjhan, 1996). The carcass fat content is reported to be much lower in the

buffalo, which is around 12 % compared to an average of 32% in European fattened cattle. Further, meat from buffalo has more protein and significantly a higher meat to bone ratio, younger animals having less fat than the older animals and also the texture is better in younger animals (Tilakaratne, 1980; Hill, 1988). Buffaloes could achieve a higher growth rate from 7 to 26 month and their feed conversion rates to meat is reported to be comparatively high (Tilakaratne, 1980). Comparative studies on weight gains have shown that the daily weight gains were 0.51 kg, 0.38 kg and 0.24 kg for improved buffalo, Sindhi and Friesian, respectively. The breeding and husbandry practices adopted by most of the paddy farmers rearing buffaloes in Sri Lanka except for the herds which are kept primarily for milking has led to inbreeding. The majority of the herds are closed herds and there is no separation of the male animals resulting in uncontrolled matings. This has led to inbreeding over the years and it is possible that the deficiencies in production and reproduction are partly due to this. Another factor is the negative selection of bulls, because bulls showing rapid growth were castrated early at the onset of sexual maturity to make them easier to handle as draught animals, thus resulting in the retention of only the small framed or slow growing bulls in the herds.

The average number of cattle slaughtered and the amount of beef produced during the period 1993 to 1998 was 187,229 per year and 20,594 MT per year, respectively. As shown in Figure 6, the availability of beef in 1998 was 20,168 MT from local sources and 98 MT from imports, which gives a per capita availability of 1.08 kg per year compared to 1.40 kg per year in 1992. The reason for this decline has been due to the lack of growth in the beef sector compared to the growth in the human population. Consumption of beef however declined from 1.19 kg per caput/year in 1986/87 to 1.02 kg per caput/year in 1996/97 (Central Bank of Sri Lanka, 1996/1997), a decline of -13% primarily due to the decline in the consumption of beef in the urban sector, while the rural and estate sectors showed a marginal increase of 0.03 kg and 0.06 kg/caput/year, respectively. The main reason for this may be the substitution by poultry meat, the

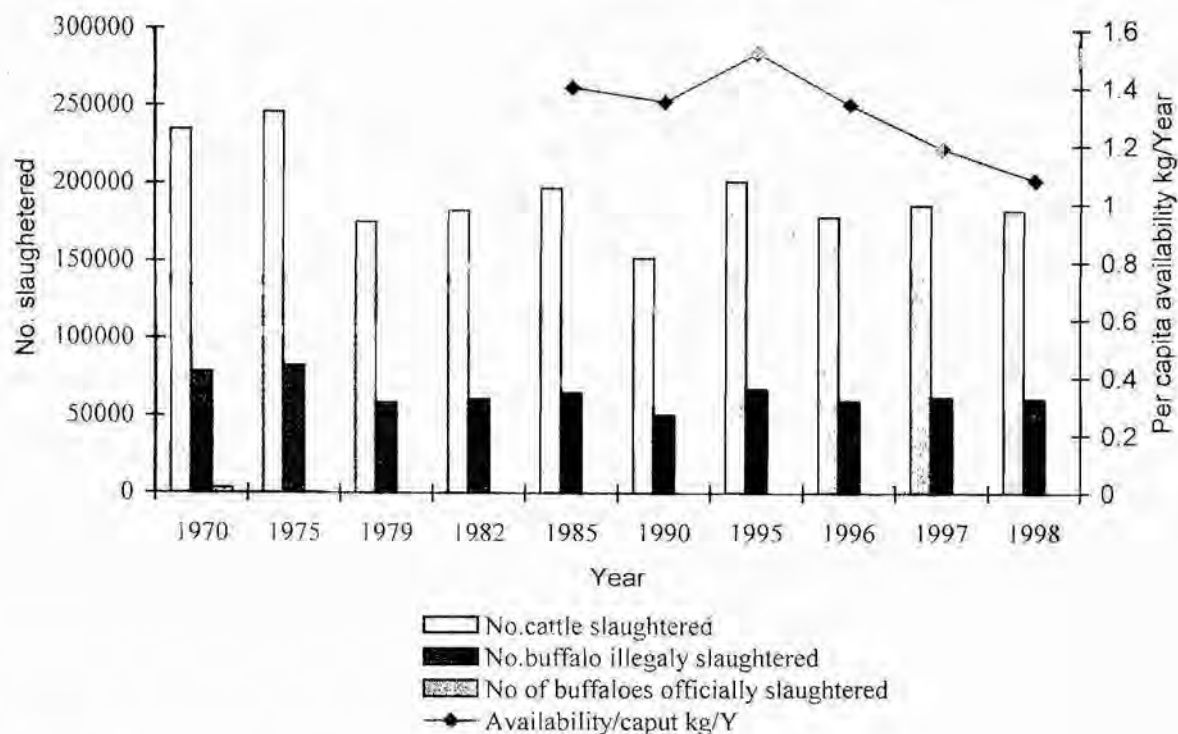


Figure 6. Trends in cattle & buffalo slaughter and per capita availability of beef
Source: Department of Census & Statistics, Central Bank of Sri Lanka. (1996/1997).

consumption of which has increased three-fold during the same period. Even though by law the slaughter of buffaloes is banned, around 30% to 40% (Figure 6.) of the beef consumed is reported to be from the buffalo (Abeygunawardena, and Abeygunawardena, 1998b).

The projection of the human population in the country for the year 2005 is expected to be 20 million persons and by 2025 it is expected to reach be 23.5 million. If the beef production of the country remains at the present level of production, then by the year 2005 the country may have to depend increasingly on beef imports, unless the consumption pattern for beef takes a considerable negative trend.

Potential and Role of R&D Efforts in Harnessing the Resources and Needs

There is no doubt that agriculture will continue to remain as the livelihood of Sri Lankan agrarian communities for many more decades to come. At present, in the estimated 1.8 million smallholder households, agriculture forms the primary source of income and of these for nearly a third of the smallholdings, agriculture is a mixed farming enterprise with crops and livestock playing complementary roles. However, the character of smallholder agriculture is continually changing as it is severely constrained by several factors. The farm land is being fragmented and the pressure on marginal lands which hitherto provided the feed resources and space for traditional agricultural operations, particularly for rearing of cattle and buffaloes have dwindled. Hence greater crop-livestock integration with more intensification of cattle and buffalo farming in these changing farming systems is a compulsion and buffalo being a multipurpose animal offers high potential, provided concerted efforts in research and development coupled with legislative changes conducive for the industry are in place.

The role of the water buffalo in rural households as a source of regular income, nutrition, draught power, organic manure, a method of cushioning the risk of crop failures and a way of forming capital have been highlighted in previous reports (Ryan *et al.*, 1980; de Silva *et al.*, 1985; Abeygunawardena and Abeygunawardena 1998a and b). In smallholder farming enterprises in most farming areas, except in the mid and hill-country wet zone regions, the buffalo has shown to offer several advantages over cattle. Buffalo milk with high fat and solid-not-fat contents fetch a higher price at the farm gate and offers the advantage of converting into a value added products, which helps to increase the profit margin several folds (Horadagoda 1998). The buffalo has been reported to be a ruminant with a higher potential to utilise marginal feed resources, a more rugged animal than its counterpart as it possesses the capability to perform well in marginal lands and withstand harsh environmental conditions. In the paddy field, the buffalo offers a definite advantage as it possesses more stamina and broader hooves. Lastly, data is emerging here as well as abroad favouring the buffalo as a better meat animal than cattle. Work done in Sri Lanka has shown that under same management conditions, indigenous buffaloes were superior to Sindhi and Friesian steers in terms of daily weight gain and meat to bone ratio (Matsukawa *et al.*, 1976), a higher nutritive value in meat because of its higher protein content with comparable levels of minerals and vitamins, and tenderness and palatability to those of cattle meat (Cyril and Siriwardene 1998).

The above mentioned advantages certainly offer great opportunities to harness the potential of water buffalo to meet the national needs. The demand for milk and milk products and meat and meat products has shown a steady increase because of the increase in population and increasing per capita incomes. Unfortunately, the growth of the livestock sector has not matched the growth in demand, except in the poultry sector and hence the country meets this deficit through imports at escalating costs. With the ultimate implementation of the international and regional trade agreements, the grant of subsidies and incentives to producers in major livestock product producing countries will cease. This will result in a significant reduction of the quantum of livestock products that will come to the world market as surpluses. The limiting supplies undoubtedly will tend to increase prices and with the deteriorating terms of trade that Sri Lanka is experiencing, it will be imperative for the country to increase the expenditure on the import of

essential animal products to satisfy the consumer demands. This will however be at the expense of other imports required for the country's quest for faster economic development. Further, both in terms of food security and self-sufficiency, there will be compulsion on the Sri Lankan agrarian sector to quickly respond to meet the national needs of its food requirements. In this context, the buffalo with its superior ability to perform under limiting conditions appear to offer a unique opportunity. However, the constraints imposed on the buffalo sector will need to be eased by continued and determined research and development efforts, backed by the state through the concomitant removal of legislative barriers which now prohibit the transport and slaughter of buffaloes.

While buffaloes are increasingly utilised for milk and meat production, their role as a provider of farm power will continue to remain as important as before. Though there has been a decline in the use of animal power in land preparation, human labour and animal power still accounts for nearly 40% of the total farm power requirement of the agrarian society (Hulangamuwa 1998). The increased fragmentation of paddy lands and the escalating cost of machinery, fuel and spare parts will undoubtedly compel the smallholder farmer to place heavy reliance on animal power. However, the conventional harnessing system and implements needs to be replaced by more modern and efficient systems in order to fully exploit the potential of the buffalo as a draught animal for use in peasant-based agriculture in Sri Lanka (Hulangamuwa, 1998).

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SYMPOSIUM – VI

Production Systems

Discussion

Q. E.R.K. Perera - Did you do a preliminary survey before you interviewed the people?

A. K.K. Pathirana - No. I agree that we should have done a preliminary survey.

Q. N.V. Thu - You said that there are problems of the availability of feed resources. In your conclusions you said that the population of buffaloes in the area should be increased. Will this not bring about malnutrition? How will the farmers respond to this?

A. B.M.A. Oswin Perera - One of the important things that were mentioned was that in that kind of terrain farmers cannot use even a hand tractor to plough. In such a situation farmers have to use human labour or animals power. There is quite a lot of tree fodder which is a potential feed resource that the farmers can use.

Comment: V.K. Gunawardena - It will be interesting to find out whether the population of buffaloes is sufficient to meet the draught power needs.

Q. Jayanthi Amunugama - I have been working in that area for a few years. My observation is that farmers who have cattle are landless farmers. This is an intense crop cultivation area. Therefore I agree with Dr. Thu that we should reduce the population or in the alternative change the management system from the extensive to a more intensive system.

A. T.S.P. Jayaweera - I agree that it is difficult to increase the population under the present management system. The biggest problem that farmers face is from stray buffaloes.

Q. B.M.A. Oswin Perera - When you say that a decision has been taken to remove the buffaloes from the National Park, are you referring to both the feral and the domestic buffalo.

A. N. Atapattu - Yes, first the domestic buffalo will be removed and later the feral buffalo. The wild buffalo is not a problem to us because the population is only about 1500 in these four Parks. They are part of the ecosystem and so they are not considered as intruders. The domestic buffalo is an intruder, because they destroy the grasslands and water holes and as a result the elephants move out of the parks in search of water and food. This has lead to the elephant-human conflict, resulting in the killing of both humans and elephants.

Q. O.P. Dhanda - We also have to confront these problems in India. I think they are brought about by broad economic pressures. What is happening is that farmers quietly lead their animals into areas around the National Parks, which are considered no man's land, and when the opportunity arises they enter the Parks to feed their animals. My experience in Gujarat is that when we identified good animals for purchase, the local people would tell us that the best animals were in the Gir lion sanctuary. But we were afraid to enter because of the fear of the lions. But when we went in with the help of the villagers, we were astonished to find the best animals right there in the centre of the sanctuary. Because of the effect of their presence on the lions, the Government of India is thinking of moving the lions into another location. The reason being that they do not want to create a conflict with the farmers.

Q. M.R. Jainudeen - About 30 years ago, a German team wanted to investigate the chromosome number of the wild buffalo. We saw the feral buffaloes near a water hole and brought down an animals with a tranquilizer gun. Unfortunately, it fell into the water hole and died. We collected blood but it was too contaminated. Have you done any tranquilizing of buffaloes and collected blood samples.

A. N. Atapattu - We have tranquilized buffaloes but not taken blood samples.

Q. M.R. Jainudeen - Have you initiated any discussions with the Department of Animal Production and Health regarding this problem?

A. N. Atapattu - No. I think this is the best forum to discuss this matter. I had a discussion with the Director General but he was not happy about removing the buffalo from the parks.

Q. K.K. Pathirana - I find the development of the peri-urban dairy industry very interesting. Can you elaborate on this?

A. A. Premasundera - One of the reasons why this has developed is because the market is very close and the demand for curd and yogurt is increasing. This industry has developed to cater to this market. Moreover, the price that the farmers gets for cow milk is much less than the price he could get for buffalo milk. If the milk is processed to curd, a farmer can earn around Rs 350 a day by keeping two buffalo cows. Whereas, he would have to keep 5 to 6 animals to get the same income. Farmers who keep cattle are gradually changing over to buffalo rearing.

Q. K.K. Pathirana - Would you say that the management system practised is a semi-intensive system?

A. A. Premasundera - Yes. It is something like a semi-intensive system.

HOUSEHOLD CONSUMPTION PATTERNS OF MILK AND MILK PRODUCTS AND MEAT AND MEAT PRODUCTS (BUFFALO AND COW) AND POLICY IMPLICATIONS: A CASE STUDY IN THE COCONUT TRIANGLE OF SRI LANKA

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Abstract: The need to increase food production has directed food policy research towards the study of the causes and impact of Government food policies on food production. The consumption expenditure of households and income are very important indicators of economic well being. Income measures the level of resources and expenditure measures the standard of living of the households. Since consumption patterns vary with time, periodic revision of consumption studies are required in the country for review of the food as well as nutritional policies of the country. In Sri Lanka there has been very few studies on household consumption behaviour particularly of livestock products such as milk and meat products. The absence of micro level data in the previous studies in SE Asia, has caused scientists to concentrate on aggregate household consumption behavior using the Linear Approximate Almost Ideal Demand System (LA/AIDS) without demographic data (Ray, 1980; Coondoo and Mujumder, 1987; Molina, 1994; Donatos, 1989; Hayes *et al.*, 1990). The main objective of this study was to estimate the household own price, cross price and expenditure elasticities of milk/milk products and meat/meat products in the Coconut Triangle in Sri Lanka. The study has also considered the affects of other food groups such as rice and wheat flour, pulses, fish/fish products and edible oils.

Keywords: Milk meat, consumption, policy implications

Introduction

Consumption expenditure and income are two important indicators of economic well being of a household. Income measures the level of resources and expenditure measures the standard of living of the household. In Sri Lanka, the consumption expenditure per capita in real terms increased at an annual rate of 1.7% over the period 1986-97. The expenditure on consumer durable goods increased by an annual rate of 4.2% while those of non-foods and services increased by 2.7%. The increase in the food expenditure was at a much lower rate of 0.2% per annum. The rate of increase of expenditure was higher in the rural sector (2.3%) as compared to urban sector (1.1%). The expenditure in the estate sector remained unchanged. In 1986, the average monthly expenditure on cow milk was Rs. 10.50 per capita or 20.2% of expenditure on all milk and milk foods. The per capita availability of cow milk in 1988 was 6.85 litres as compared to 2.91 litres of buffalo milk. Cow milk contributed to 12.85 calories, 0.60 grams of proteins and 0.08 grams of fat daily per capita food intake. Comparatively buffalo milk contributed to 9.32 calories; 0.34 proteins and 0.07 grams of fat daily per capita intake (Livestock Statistics, 1992). Among the main food items, the monthly per capita consumption of rice increased from 8638 to 8845 grams between 1986 to 1997. The consumption of wheat flour and bread increased from 1877 to 2661 grams and 734 to 837 grams, respectively over the same period. The average calorie consumption increased from 2204 calories per capita in 1987 to 2337 calories in 1997. The calorie gain was comparatively higher for the lower 40 percent of the spending unit when compared to the rest. Overall, rice was the dominant source of energy intake accounting for 44% of the total calorie intake followed by coconuts (12%) and bread (10%) (Central Bank of Sri Lanka, 1997).

It is evident that developing countries such as Sri Lanka, require government policies to overcome malnutrition. The need to increase food production has directed food policy research towards studying the causes and impact of government policies on production and productivity. However, there have been very few studies on household consumption behaviour, which would provide

information to formulate guidelines for framing malnutrition policies in the country. The absence of micro-level household consumption data in the previous studies in SE Asian countries, has caused scientists to concentrate on aggregate household consumption behaviour, using different economic modeling, such as Linear Approximate Almost Ideal Demand System (LA/AIDS) without demographic data that may contribute greatly to household food expenditure patterns (Ray 1980; Murti, 1985; Condoo and Mujumder, 1987; Mergos and Donatos, 1989; Hayes *et al.*, 1990; Molina, 1994).

The main objective of this study is to determine the major socio-economic factors that influence household consumption expenditure on milk and milk products (cow and buffalo) in the Kurunegala District of the coconut triangle of Sri Lanka. In order to analyze this component of the expenditure, a share model consisting of other food commodities in the household food balance sheets, such as rice and wheat flour, meat and meat products, fish and fish products, edible oils, horticultural products, such as fruits and vegetables and all the other food items were included. This analysis provided estimates of own-price expenditure elasticities of milk and milk products (cow and buffalo) and cross expenditure elasticities of milk and milk products with other major food commodities included in the household food balance sheets.

Data Collection

Kurunegala and Polgahawela Divisional Secretariat divisions were selected purposively from the Kurunegala district in the coconut triangle. The selection was done on the relatively high percentage distribution of buffalo (6.9%) and cattle population (13.8%) of the total population in this district. From each division 60 consumer households were selected randomly making a total of 120 representing the district. A field survey questionnaire was used to collect data on household demographic characteristics, employment patterns, farm and non-farm incomes, expenditure on monthly consumption patterns of foods and non-foods and sources of purchases, prices of consumer goods from the selected households.

Analytical Methodology

The analytical method is based on the Almost Ideal Demand System (AIDS) model developed by Deaton and Muellbauer (1980). This is a popular method for estimating the price and income elasticities when expenditure or budget data are available. The expenditure share equations of the AIDS model for each commodity or commodity group are derived by differentiating an expenditure function of the form,

$$\ln e(u, p) = \alpha_0 + \sum_j \alpha_j \ln p_j + \frac{1}{2} \sum_j \sum_i r_{ij} \ln p_i \ln p_j + u \beta_0 \prod_j p_j^{\beta_j} \quad (1)$$

where $e(u, p)$ is the expenditure share function for utility u , and price vector p . Applying Shepherds lemma to the expenditure function yields a demand system in terms of utility and prices. As the utility is not observed, the resulting demand system cannot be estimated. Using the inverse of the expenditure function to express the utility in terms of incomes and prices (indirect utility function) results in the budget share equation of the form,

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln (x/P) \quad (2)$$

where w_i is budget share of food i ; p_j price of food j , x is the total expenditure; P is price index defined by,

$$\ln P = \alpha_0 + \sum_j \alpha_j \ln p_j + \frac{1}{2} \sum_j \sum_i \gamma_{ij} \ln p_i \ln p_j \quad (3)$$

The theoretical properties of summation, homogeneity in prices and income, and symmetry of the cross effects imply the following restrictions on the demand function (2),

$$\text{summation} \quad \sum_{i=1}^n \alpha_i = 1; \quad \sum_i \gamma_{ij} = 0; \quad \sum_i \beta_i = 0 \quad (4.1)$$

$$\text{homogeneity} \quad \sum_j \gamma_{ij} = 0 \quad (4.2)$$

$$\text{symmetry} \quad \gamma_{ij} = \gamma_{ji} \quad (4.3)$$

The other restriction related to concavity of the expenditure function has no parametric representation. The demographic effects are incorporated into the model by allowing the intercept in (2), to be a function of the demographic variables (Heien and Pompelli, 1988),

$$\alpha_i = \rho_{io} + \sum_{j=1}^s \rho_{ij} d_j \quad (5)$$

where, d_j is the j th demographic variable. Incorporating (5) into (3) with error term v_i ,

$$w_i = \rho_{io} + \sum_{j=1}^s \rho_{ij} d_j + \sum_j \gamma_{ij} P_j + \beta_i \ln(x/P) + v_i \quad (6)$$

With the summation requirement under the specification of demographic variables requires,

$$\sum_i \rho_{io} = 1 \quad \text{and} \quad \sum_i \rho_{ij} = 0 \quad (j = 1, 2, \dots, s) \quad (7)$$

Due to the price index in equation (3), the system of equations becomes non-linear and requires estimation of a large number of parameters. Hence the overall price index in this study is approximated by Stone price index, $\ln P = \sum w_i \ln p_i$. The AIDS model using Stones index is termed Linear Approximate Almost Ideal Demand System (LA/AIDS). The consumer expenditure allocation could be presented in two stages. In the first stage, the consumer determines the allocation of his total expenditure between several commodity groups such as food, housing, transport, recreation, education, health etc. It is assumed that these food groups used in the study are weakly separable from all the other commodity groups used by the consumer. In the second stage, the expenditure is allocated among the different food groups. The first stage of the food expenditure is a function of food prices, non-food prices and household income (Beiri and de Janvry, 1972). This study is concentrated in the second stage of the budgeting process, i.e. to estimate a separable demand system for food. This specification assumes that the marginal rate of substitution between food groups such as milk /milk products, cereals, edible oils is independent of the non-food commodities such as education and housing.

The Marshallian price elasticity (uncompensated) of commodity i with respect to commodity j th price in AIDS expenditure model is given by,

$$E_{ij}(m) = \frac{\gamma_{ij}}{w_i} - \frac{\beta_i w_j}{w_i} - \delta_{ij} \quad (8)$$

where $\delta_{ij} = 1$ when $i=j$, otherwise $\delta_{ij} = 0$.

$$\text{The expenditure elasticity } e_i = 1 + \frac{\beta_i}{w_i} \quad (9)$$

Using the Slutsky equation, the compensated or Hicksian price elasticity

$$E_{ij}(h) = E_{ij}(m) + w_{jei} \quad (10)$$

The demographic variables on the budget share (w_i) will affect the magnitude but not the signs of the elasticity coefficients. The classification of goods as to luxuries or necessities is not affected by the presence of demographic variables (Heien and Pompeli, 1988).

Results and Discussion

The monthly expenditure of different food commodities are shown in Table 1. Rice and wheat flour contributed to nearly 16 % of the monthly expenditure among the households. The expenditure on fish and fish products was as close to the basic staples (15.2%) due to its higher prices and its better availability due to proximity to the coastal areas such as Chilaw and Negombo. Vegetables and fruits costs 14% of the total monthly household expenditure. Milk and milk products (both cow and buffalo) amounted to nearly 13% of the total expenditure. The other food groups including sugar, beverages, potato, eggs and condiments cost 23% of the total food expenditure. The expenditure on meat (mainly beef and chicken) was 8% mainly due to the high prices of these commodities. The expenditure on pulses was the least due to their low prices. Coconut and coconut oil were important among the edible oils which accounted for 6.6% of the total expenditure. The average expenditure on all foods was around Rs. 7250/month.

All the households reported that they consume powdered milk and 12.5 % condensed milk. Cow milk was consumed by only 5 % of households due to their low availability, butter (Margarine) by 8.3 % and cheese by 2.5% of the total households. Buffalo curd (or yoghurt) was commonly consumed by 55% of the households. Among meats nearly 7% of the households consumed beef and 76% chicken and the balance for meat products (Figure 1). Nearly 4% also consumed beef/chicken processed products such as sausages and meat balls. The monthly household expenditure of powdered milk was Rs 694 followed by Rs 90 for buffalo curd, Rs 27 for cheese and Rs 25 for condensed milk. The household expenditure of cow milk was nearly Rs 11/month (Figure 2). The household monthly expenditure on beef /chicken meats and meat products amounted to Rs 579 of which monthly beef consumption expenditure amounted to Rs 39, chicken Rs 442 and others Rs 97 (Figure 3 and 4). Majority of the food products including milk/milk products (other than liquid milk) meat and meat products were purchased from private traders (95%) and cooperatives. The average distances traveled amounted to nearly 0.8 km to purchase these commodities. The frequency of monthly purchases was around 11 times to the closest markets.

Table 1. Monthly household food expenditure

Food Group	Expenditure (Rs/month)	Expenditure Share (%)
Rice and Wheat flour	1175.96	16.2
Pulses	325.81	4.5
Milk and milk products	929.51	12.9
Meat and meat products	578.60	8.0
Fish and fish products	1109.60	15.2
Edible oils	475.26	6.6
Horticultural products	1010.20	14.0
Others	1633.40	22.6
Total	7238.49	100.00

Regression results

The LA/AIDS model was estimated by the non-linear seemingly unrelated regression method with homogeneity and symmetry conditions imposed. Since the data employed was in the form of panel data, a fixed effects estimator was employed to control for potential correlation between omitted variables and the regressors. The restrictions imposed were tested by the log-likelihood ratio test. The results indicated that with the demographic variables included in the model both

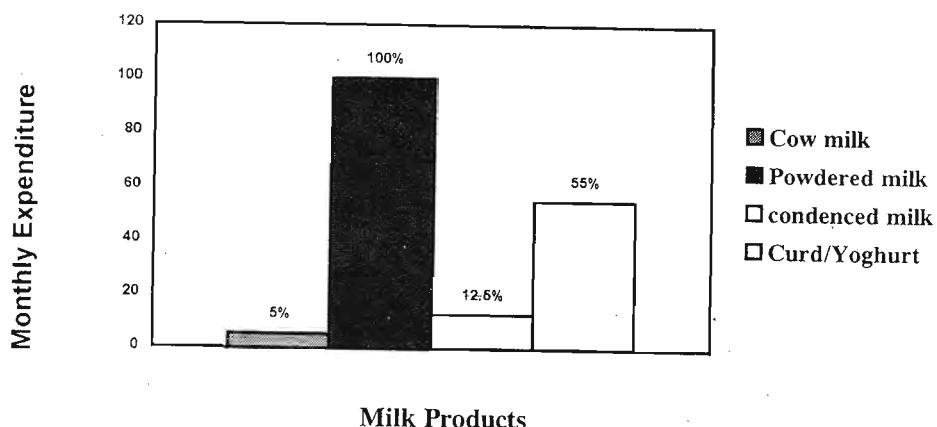


Figure 1. Expenditure on milk products (Percentage reporting)

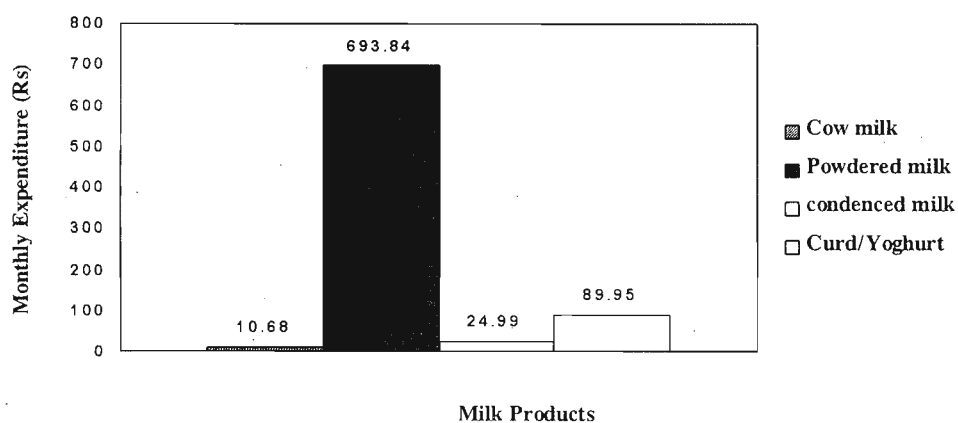


Figure 2. Expenditure on milk products (Rs. per household)

homogeneity and symmetry restrictions could not be rejected at 5% significance level. Hence the model was estimated with demographic variables with the inclusion of both restrictions (Table 2).

Table 3 and 4 shows the results of the expenditure share equations of rice and wheat flour, pulses, milk/milk products, meat/meat products, fish/fish products, edible oils, horticultural products (fruits and vegetables) and other food group estimated by non linear seemingly unrelated regression procedure.

Table 2. Log - likelihood test for homogeneity and symmetry

	Without demographic variables	With demographic variables
Homogeneity 5 d.f	21.43*	6.59
Homogeneity and symmetry 25 d.f	39.10*	21.44

*Rejected theoretical hypothesis at 5% level of significance

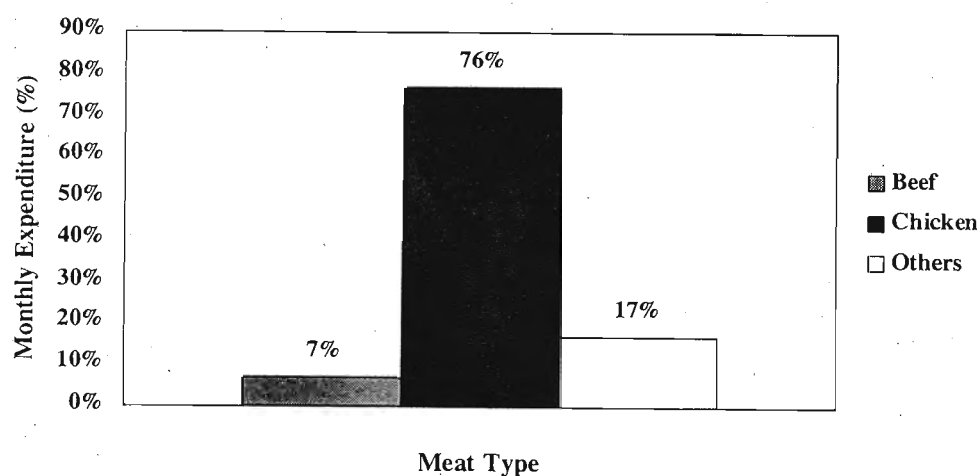
Table 3. Estimated coefficients for the LA/AIDS model for different food commodities

Items	Mean budget share	Constant	Rice and wheat flour	Pulses	Milk/milk products	Meat/meat products	Fish/fish products
Rice and wheat flour	0.162	0.5112	0.0229*	-0.0023*	-0.0018	-0.0026	-0.0009*
Pulses	0.045	0.4133	-0.0112*	0.0524**	-0.0013	-0.0007*	-0.0014
Milk/milk products	0.129	-0.2008	-0.0127*	-0.0876	0.0239**	-0.0138	-0.0034
Meat/meat products	0.080	0.0679	-0.0003*	-0.0133	-0.0029	0.0576**	-0.0019
Fish/fish products	0.152	0.1654	-0.0339	-0.0071*	-0.0122*	-0.0003	0.0248**
Edible oils	0.066	0.1139	0.0122*	0.0018	-0.0152	-0.0012	-0.0002*
Horticultural products	0.140	0.4561	-0.0034	-0.0172	-0.0100*	-0.0032	-0.0007*
Other food products	0.226	-0.1132	-0.0031	-0.0192	-0.0169	-0.0076	-0.0091

Table 3 (Contd.). Estimated coefficients for the LA/AIDS model for different food commodities

Items	Edible Oils	Horticult Products	Food expenditure	Age	Sex	Education	Family size
Rice and wheat flour	0.0019	-0.0113	-0.0403*	0.2079	-3.8940	0.8808	1.2688
Pulses	0.0005	-0.0133	-0.0067*	0.0013*	0.9102	0.0668**	0.1572
Milk/milk products	-0.113	-0.0058	-0.0031*	-0.2524*	-0.9349*	0.5498*	-1.0023
Meat/meat products	-0.008	-0.0379	-0.0094*	-0.1145*	-0.0424*	0.3039*	-0.6285*
Fish/fish products	-0.052	-0.0054	-0.0011*	0.0671**	2.3028	0.4170*	-0.5895
Edible oils	0.0138*	0.0001	-0.0052*	0.0647	-1.3480*	0.0067*	0.4435
Horticultural products	-0.001	0.0261*	-0.0101	0.1188	0.2169	-0.1447*	0.7294
Other food products	0.0064	0.0002	-0.0803	0.0362	-3.0540*	-0.2980*	-0.7156*

*, ** - Significant at 5% and 1% level

**Figure 3.** Expenditure on meat products (Percentage reporting)

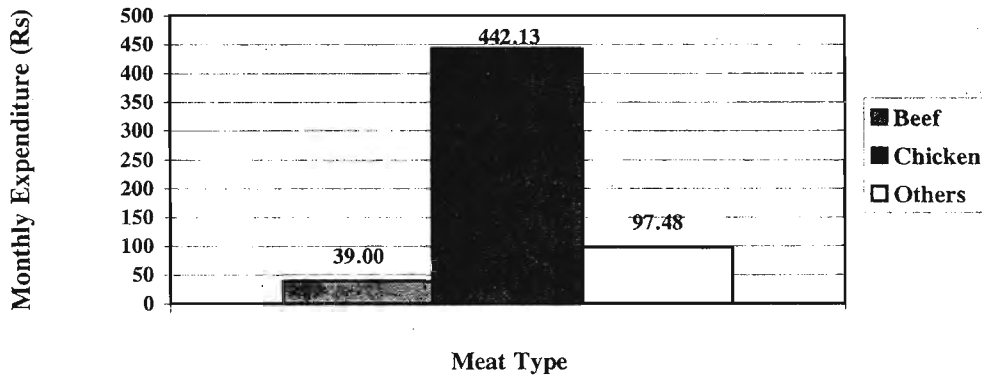


Figure 4. Expenditure on meat products (Rs. per household)

The non food equation was deleted from the model because of singularity in the variance matrix when all equations were included. The parameters of the deleted equations were obtained from the summation condition of the demand parameters. For the milk/milk products expenditure share equations most of the coefficients, including the demographic variables are significant at the 5% level, suggesting a high amount of price and non-price responsiveness of the expenditure share.

The coefficients of age for milk/milk products is negative indicating that with age households become conscious of the higher fat levels of milk (cholesterol levels) and their effect on their personal health and a readjustment of the expenditure pattern accordingly. The coefficients for family size is negative for milk/milk products; meat/meat products and fish/fish products. This result indicates that as the family size increases for a given level of expenditure and prices, households are compelled to adjust their pattern of expenditure towards relatively inexpensive commodities such as rice and wheat flour; edible oils and away from expensive commodities such as milk /milk products, meat/meat products and fish/fish products. The level of education seems to have a significant impact on the expenditure patterns on the animal proteins (milk/milk products; meat/meat products and fish/fish products) and vegetable proteins (pulses) as compared to cereals.

The results showed that milk/milk products as well as meat/meat products are income inelastic as that of other commodities i.e household consumption patterns are less responsive to changes in income. This may be related to the basic nature of these food commodities for the household. The food expenditure elasticities of all commodities inclusive of milk/milk products, meat/meat products are positive, indicating that all are normal goods, the consumption of which will increase with increase in income. All the expenditure elasticities were less than one with varying values. The results also indicated with increase in incomes, consumers tend to spent proportionately less on rice and wheat flour, edible oils, horticultural products and other foods; and more on milk/milk products; meat/meat products and fish/fish products.

The estimated compensated and uncompensated price and expenditure elasticities are conditional elasticities and all are second stage estimates (Hayes *et al.*, 1990). The marginal expenditure shares were calculated by multiplying the estimated expenditure elasticities by the expenditure shares. The results show that for any increase in food expenditures, the largest percentage increase of 4.9%, 3.8%, 3.5% will be allocated to meat/meat products, milk/milk products and fish/fish products respectively. The expenditure changes on rice and wheat (1.9%) and pulses (1.5%) will remain substantial although their significance will decline over time. The food expenditure elasticities were converted to total expenditure elasticities by multiplying the total expenditure elasticities for food by the respective food expenditure elasticity (Hayes *et al.*, 1990; Blanciforti

and Green, 1983). The results show that all commodity groups are inelastic with varying elasticities.

Table 4. Expenditure elasticities and marginal expenditure elasticities

Food group	Food expenditure elasticity	Total expenditure elasticity	Marginal expenditure share elasticity
Rice and wheat flour	0.1158	0.0691	0.0188
Pulses	0.3368	0.2237	0.0152
Milk/milk products	0.2939	0.1489	0.0379
Meat/meat products	0.6126	0.4911	0.0490
Fish/fish products	0.2286	0.1099	0.0347
Edible oils	0.1312	0.0798	0.0087
Horticultural products	0.0335	0.0076	0.0046
Other foods	0.1131	0.0071	0.0256

The Marshallian own price elasticity computed from equation (8) for milk/milk products and meat/meat products was -0.431 and -0.221, respectively. Although inelastic this indicates that a uniform percent decrease of prices would elicit a greater demand for milk/milk products as compared to meat/meat products. The cross price effects were generally negative (other than pulses) suggesting that most food groups are complements. However most cross effects were weak in the results. The compensated or Hick's elasticities provide a more accurate picture of cross-price substitution between food groups, since they measure substitution effects net of income (Molina, 1994). All estimated Hicks' own price elasticities were negative and was -0.381 and -0.187 for milk/milk products and meat/meat products, respectively. The compensated cross price elasticities between rice and wheat flour and milk/milk products (-0.193) and meat and meat products (-0.149), edible oils and milk /milk products (-0.007), meat/meat products (-0.002) and showed complementarity between the food groups. All other compensated cross price elasticities were positive, suggesting substitution effects between these food groups.

Conclusions and Policy Implications

The household consumption data gathered from the coconut triangle district of Kurunegala, were used to investigate the expenditure patterns. Eight commodity expenditure share equations were estimated with LA/AIDS model. The results indicated that all commodity groups (although inelastic) are quite responsive to expenditure changes with milk/milk products and meat/meat products showing the largest responses. The food demand is also quite responsive to price changes i.e. as prices of these commodities increase, expenditure allocation is expected to decrease. The demographic variables such as age, sex, education, family size are important in explaining the observed differences in the expenditure patterns of foods.

The results also indicated that if food supply (milk/milk products or meat/meat products) can be increased to maintain the market prices constant, increases in consumer incomes will result in improvements in food consumption. The policies aimed at increasing food supply (milk/milk products or meat/meat products) should be coordinated with simultaneous increase in consumer incomes to it more effective to the nutrient deficient consumer groups. If the increase in food supply is costly, income transfer from higher to low income groups could be done through taxes or increase in poverty alleviation programmes directed towards lower income groups.

With the income elasticity for foods (milk/milk products) less than unity, only part of any incremental income of the consumers will be spent on foods (milk/milk products). Hence augmenting the incomes of low income groups will positively influence the relative purchasing

power of other goods. If increased food consumption contribute to higher income for crop producers this would trigger growth in the dairy sector. This would have a spin-off effect from net increases in rural incomes and spending of non-farm items, which could create additional increase in employment and incomes in rural farms.

The changes in demographic factors such as education, sex, age and family size can cause the demand function of milk/milk products to shift over time. Further, the understanding of the effect of demographic factors on foods such as milk/milk products could improve the accuracy of forecasts or future predictions of food expenditure. For example, larger families are compelled to adjust their consumption patterns of foods, such as milk/milk products to relatively inexpensive commodities such as liquid milk as compared to more expensive powdered milk. Better educated householders also appeared to be influenced to consume more expensive foods.

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EFFECT OF FARM AND HERD SIZE ON ECONOMICS OF BUFFALO MILK PRODUCTION IN CENTRAL PUNJAB, PAKISTAN

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Abstract: Farm and herd size has shown significant effects on cost of milk production and other economic parameters. The objectives of present study were to evaluate the economics of milk production under different types of landholdings and herd size. A total of 322 farmers engaged in buffalo farming were interviewed and divided in two main classes, (i) landholding class (LHC) and (ii) animal holdings class (AHC). These classes were subdivided into landless, small, medium and large groups according to the land holdings and herd size. The collected data were used to study the different aspects of milk production viz., input: output, gross margins, daily revenue (DR), daily expenditure (DE), daily income (DI), cost benefit ratios (CBR) per liter milk produced. The following observations are made:

- (a) The inputs and output were higher in large groups.
- (b) CBR was higher in small and large farmers in LHC and AHC respectively.
- (c) LL farmers were getting minimum return from dairy enterprise.
- (d) Farmers are getting almost 50% profit /unit of expenditures.
- (e) DI was almost equal in small and large groups in LHC.

Keywords: Milk production, herd size, landholdings, economics

Introduction

A significant proportion of the national buffalo herd (60%) is maintained by small to medium farmers who have 1-6 buffaloes. Whilst, herds of 7-20 buffaloes are maintained by 34% farmers, 6% farmers keep more than 20 animals (Anon., 1998). Farm and herd sizes have shown significant effects on cost of milk production and other economic parameters (Baruah and Sarkar, 1997). Therefore, the objectives of the present study were to evaluate the economics of milk production under different production systems and herd sizes.

Materials and Methods

A 30-45 minute questionnaire was used to interview the 322 respondents engaged in buffalo farming, to obtain information on different aspects of milk production systems, herd size, inputs and outputs, using the method of Poate and Daplyn (1993). The farmers were categorised into two classes, (i) landholding class (LHC) and (ii) animal holdings class (AHC). LHC was subdivided according to the size of landholdings viz. (a) landless farmers (LL), (b) less than 2 acres of land (Small), (c) from 2 to 12.5 acres of land (Medium) and more than 12.5 acres (Large). The classification according to the animal holdings size (AHC) was (a) 2 or less than 2 animals (Small), (b) from 2 to 6 animals (Medium), and (c) more than 6 animals (Large). The data collected were used to study the different aspects of milk production viz., input:output, gross margins, cost benefit ratios per litre of milk produced.

Results and Discussion

The milk was sold at the rate of Rs. 9.50 per kg or Rs.380 per 40 kg. In the case of landless farmers, the lactation length was slightly longer than other classes of farmers (10 months vs. 9.5 months) but the lactation yield was less. The calculations were based on the calving interval (CI). The CI was 16 months with LL farmers and 15 months with other classes of farmers. To calculate the total margins, the expenditures were calculated for 16 and 15 months, respectively. The

depreciation of animals was calculated by the method described by Deoghare and Bhattacharyya (1994).

Deprecation of animal = original cost on animal/productive life

The interest (14% per annum) on fixed costs was calculated and added to the total expenditure. It was assumed that one animal (female for replacement or male) would be raised along with the buffaloes. The estimated price of young stock was added in return. Animals were fed concentrate only during the first few months of lactation. They were grazed free of cost during different months of the year, depending upon the availability of the grazing area and fodder. Therefore, the cost of fodder during the grazing period was excluded from the total fodder cost. The total cost (inputs) on keeping one buffalo for 15-16 months was Rs.15,690 to Rs.16,910 for landless and large framers, respectively in LHC. The gross margins, input:output, net income, production cost per litre of milk produced and other costs on a single buffalo basis were calculated and given in Table 1.

The sum of all the returns (outputs) on a single buffalo basis was Rs.24,681 to Rs. 26,655 for LHC and margins were Rs.9,029 to Rs.9,745, respectively. When these margins were distributed for CI, the monthly income (MM) was found to be Rs.564 to Rs.650 and Rs.425 to Rs.530 for LHC and AHC, respectively (Table 1). The actual cost of production per litre of milk produced was also calculated. For this purpose, only the actual expenditure incurred during the lactation period was taken. The results showed that expenditure to produce one litre of milk (MC/litre) ranged from Rs.6.47 to Rs.6.32 from LL to larger farmers (Table 1). The cost of milk production in different farmer classes under different classifications invariably suggested that the large farmers, whether having own land or cultivated, were expending less to produce one litre of milk. The cost benefit ratio (CBR) for production of one litre ranged from Rs. 0.46 to Rs. 0.62 in different groups of farmers. The CBR was calculated on net profit per litre basis. If costs of personal labour, animal depreciation and interest rates are not included, the CBR could be higher.

Table 1. Input:output, gross margins and cbr/l produced

	Input	Output	Margins	MM	MC/l	CBR/l	GMR
LHC							
LL	15650	24680	9029	564	6.47	0.46	1.57
Small	15009	24888	9878	658	5.86	0.62	1.62
Medium	15964	25211	9247	616	6.22	0.51	1.59
Large	16910	26655	9745	650	6.32	0.50	1.59
AHC							
Small	16020	22832	6811	425	6.45	0.47	1.42
Medium	16431	23848	7417	494	6.33	0.50	1.45
Large	16412	24361	7949	530	6.15	0.54	1.48

The input:output ratio per lactation milk yield was found to be 1:1.46 to 1:1.62 in different groups of farmers. To calculate the ratio, actual expenditure made during lactation period was divided by return from milk only. The ratio between input and output for gross margin (GMR), including all expenditures and returns for CI is given in Table 1. The results revealed that with increase in farm size, the total expenditure on milk production also increased in LHC. This trend was also observed by many other workers (Shiyani *et al.*, 1989; Rajiv *et al.*, 1992). This increase in expenditure could be attributed to better feeding and management. In contrast to these findings, some other researchers found that increase in farm size resulted in reduction in total cost (Goswami and Rao, 1992; Deoghara and Bhattacharyya, 1994; Chaudhry *et al.*, 1997). The reduction in total cost might be due to bulk purchase of inputs and use of farm produced agri-by-products for dairy animals. The input output ratio suggested that with increase in farm size, the return was increased. It was noted that on an average Rs. 0.50 is the net income per single rupee spent on milk production. In other words, there is approximately, a Rs. 3.0 profit per litre or a 50% net profit. Although the cost of production on large farmers is higher, due to better lactation yield and price, they are in profit and are viable (Chaudhry *et al.*, 1997). The daily revenue (DR),

daily expenditure (DE) and daily income (DI) in LHC and AHC is shown in Figs. 1 and 2. In the previous studies, the net income per litre ranged between Rs.0.26 to Rs.0.53 (Shiyani *et al.*, 1989; Rajiv *et al.*, 1992), but in the present study, the values ranged from Rs.3.01 to Rs.3.64 during the lactation period. The better return rate per litre and input:output ratio than other workers (India) may be due to higher price for milk sold. The city milk shopkeepers pay almost the same price as in the research area. The income per month was in the range quoted by the other workers (Deognare and Bhattacharyya, 1994).

In case of large farmers or herd size, the inputs were better. This was reflected in better milk yield, daily income and reduced production cost (Deoghare and Bhattacharyya, 1994). The landless farmers do not consider the value (in cash) of their own or family member's labour and time spent in livestock related activities. If we exclude this factor from the cost, then their daily income could be higher. To achieve the maximum return from this enterprise, shorter calving intervals (CI) with longer lactation and high lactation yields are necessary factors.

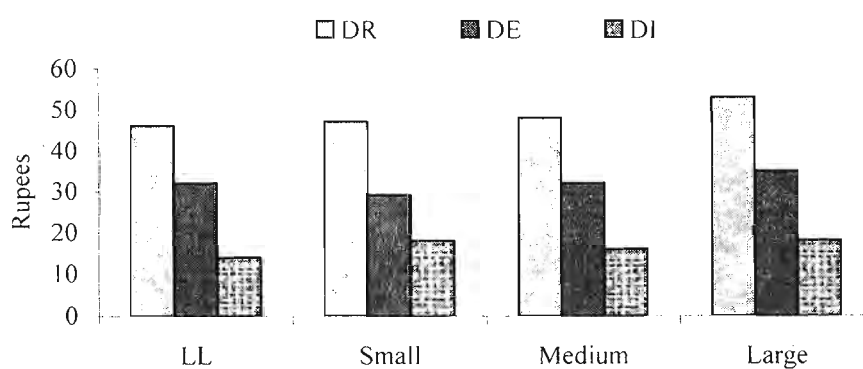


Fig. 1. Daily revenue, daily expenditure and daily income in landholding class

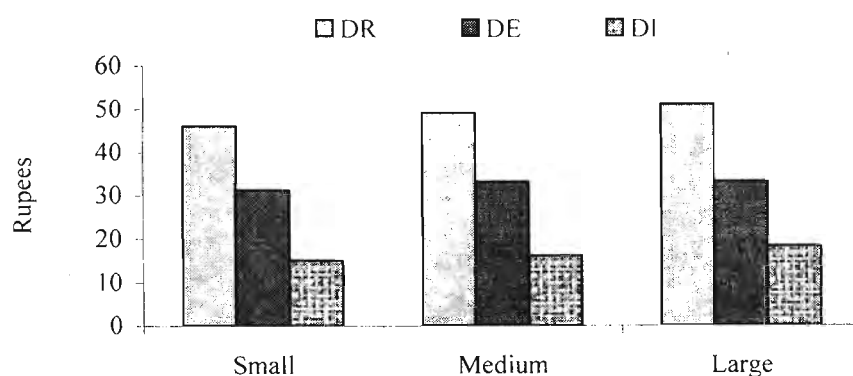


Fig. 2 Daily revenue, daily expenditure and daily income in animal holding class

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EVALUATION OF THE KEEPING QUALITY OF BUFFALO MILK

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Abstract: Fifty lactating buffaloes from two farms located in the dry zone and the mid-country were used in this study. From each animal, 2 milk samples were collected directly from the udder (all quarters); one into a sterile glass bottle (25 ml) for bacteriological studies and the other into a clean dry plastic bottle (50 ml) for evaluation by platform tests. On completion of milking, two further samples were collected from the receptacle as described. California Mastitis Test (CMT) was performed on the udder sample of each animal at the time of milking. All samples were assessed for somatic cell count (SCC) and total plate count (TPC). Milk samples were cultured on blood agar and MacConkey broth. Milk samples were also subjected to Methylene Blue dye Reduction Test (MBRT), resazurine test (RT), 68% alcohol precipitation test and clot-on-boiling test.

Four per cent of the udder samples were positive for MBRT after one hour. Those buffaloes may be affected with sub clinical mastitis. In contrast, 42% of the bulk milk samples were positive for MBRT showing a high degree of contamination after milking. According to the results of CMT, 2% of the animals gave a score of 3, 3% had a score of 2 while the remaining were negative. RT also indicated similar results as for MBRT. In the boiling test, 12% of both the udder and bulk milk samples clotted. Similarly alcohol precipitation test too, gave higher positivity in milk collected at both stages indicating the low sensitivity of these tests. In samples positive for the CMT, the SCC ranged from 1.4×10^6 – 6.6×10^6 . Milk from the receptacle had a very low SCC. Conversely the TPC of the bulk samples gave an average of 2.45×10^5 while the udder samples had a mean bacterial count of 1.3×10^4 . These observations illustrate that contamination was not due to udder infections but due to unhygienic milking practices. Milk from the buffaloes in the farms studied was used for curd preparation. Fifteen per cent of the samples indicated the presence of spore forming *B. cereus*, a heat resistant bacterium that is capable of contaminating curd. Forty three per cent of the samples showed contamination with coliform, which is destroyed by heating and is of less hazardous. This study clearly shows that milk is subjected to a high degree of contamination after being drawn from the udder and the need to increase the awareness of this phenomenon if farmers are to produce better quality milk for which increased remuneration is provided.

Introduction

The quality of milk which encompasses the composition and hygienic character is one of the key factors in a successful dairy enterprise that is dependant on many factors such as breed, feed, lactation environment and the method of milking. Indeed, the maintenance of the hygienic quality of milk once drawn from the udder is pivotal for proper processing and manufacturing of dairy products.

Contamination of fresh milk has become a major issue in purchasing milk as most milk processing establishments now prefer to produce highly marketable “ready to drink” liquid milk products. These products have become popular since they have a longer shelf life without a need for refrigeration during marketing and storage.

Buffalo milk is used in the preparation of dairy products, worldwide. In Italy, buffalo milk is utilized in the preparation of Mozzarella cheese where the keeping quality of milk needs to be very high in order to produce good quality cheese. Buffalo milk is used in a wide variety of dairy products in India including in the preparation of infant formulae. In Pakistan, about 70 per cent of the milk produced is obtained from the buffalo and a major portion of this is processed for dairy products. Buffalo milk is widely consumed in many developing countries and is produced largely

by small holder dairy farmers where husbandry and milking practices allow considerable opportunities for contamination (Ganguli, 1997).

Contamination of milk could either be directly by endogenous organisms causing udder disease or by external sources i.e. after the milk has been drawn from the udder. In the buffalo, the tight sphincter in the teat is an important factor for the marked reduction of *in vivo* contamination of milk (Horadagoda, 1998; Horadagoda, *et al.* 1993).

Most of the buffalo milk produced in Sri Lanka is converted to "curd", a popular fermented dairy product, which is marketed generally without refrigeration. The preparation of curd is dependent on clean milk, since contaminants especially with heat stable bacteria could have an adverse effect on the quality of curd, especially in relation to taste. However at present, the importance of clean milk production is poorly understood by dairy farmers. One of the contributing factors to this situation is that the farm gate milk price is based mainly on the total solid content. Therefore, very little attention is directed to the hygienic quality of milk (Horadagoda, 1999).

In Sri Lanka, the low farm gate price of milk has repeatedly been cited as one of the major constraints for a sustainable dairy industry. Indeed milk pricing is a complex issue which has to examine several factors, but the possibility of including an addition payment for hygienic quality of milk will be an incentive and stimulate farmers to be concerned on the quality. It will also provide an opportunity for milk procuring agents to purchase milk more suited to produce "ready to drink" products.

Bacterial contamination of milk is generally assessed by the dye reduction tests and the alcohol precipitation test. The use of these tests as indicators for contamination is dependent on a scoring method that reliably reflects the degree of contamination. Each country adopts a different scoring system as it is influenced by factors such ambient temperature, water quality and logistics related to handling of milk. The objective of this study was to develop a cost-effective, rapid and sensitive scoring system for Sri Lanka that would enable the detection of contaminated buffalo milk at collecting centres.

Materials and Methods

Milk samples for this study were collected from 50 randomly selected buffaloes managed in two farms (A and B). Twenty five samples were collected from Farm A located in the dry zone, while 25 were obtained from Farm B in the mid country.

All milk samples were collected at the time of morning milking. Two milk samples were collected directly from udder of the selected cows. One sample (25 ml) was taken into a sterile container for bacteriological studies while the other (50 ml) was collected into a clean bottle for routine platform tests. On completion of milking two further samples for the same purposes were taken from the receptacle that was used at milking. Further, the California Mastitis Test (CMT) was performed on each animal at the time of milking. In addition to milk, samples of water, which was used in the washing of the udder and utensils in the milking parlour were also collected. All samples were transported to the laboratory within two hours of collection in a polystyrene box maintained at 4°C.

All platform tests were carried out according to the methods described in AOAC, (1980). Briefly, the tests performed included an assessment of appearance, smell, taste (AST) and an evaluation of contamination by two dye reduction tests; methylene blue reduction test (MBRT), and the resazurine test (RT). The clot on boiling tests (COB) and the alcohol precipitation test (68%) were also performed. The acidity in milk was evaluated by a titration with 0.1% sodium hydroxide in the presence of phenolphthalein and the pH of milk was measured directly using a pH metre (Kent, EIL 1020). The somatic cell count (SCC) was carried out as described by Fay (1959). The

total plate count, the presence of coliform bacteria and *B. Cereus* activity were evaluated according to the method reported by Dhakal *et al.* (1991).

Results

In farm A, prior to milking the sheds were cleaned and the udder was washed with liberal quantities of clean water accessed through a rubber hose. They also practised the strip cup-test prior to milking. In contrast, in farm B the udder was washed with unclean water collected in a large container. Moreover, the udder was not washed adequately prior to milking.

Table 1. Dye reduction tests in udder and bulk milk samples at one hour in Farms A and B.

Farm (number of animals)	MBRT Udder	MBRT Bulk	RT Udder	RT Bulk
Farm A (25)	1	2	0	1
Farm B (25)	1	19	2	18
Mean	2 (4%)	21 (42%)	2 (4%)	19 (38%)

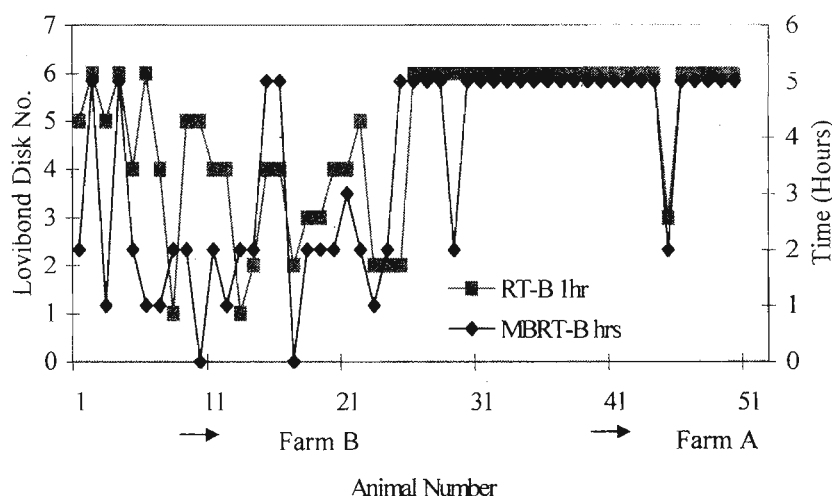


Figure 1. Indicates the Methylene blue dye reduction test and the resazurine dye reduction test results of the bulk milk samples in individual animals.

The MBRT was examined hourly, for 5 hours. After one hour, only 4% of the 50 udder samples were positive in the MBRT. In contrast, 42% of bulk milk samples gave a positive reaction at one hour while 56% were positive at 3 hours. The RT also showed similar results to that of MBRT. Figure 1 shows the relationship of the MBRT and RT results of individual buffaloes between the udder and the bulk samples. Udder samples had a much lower contamination score when compared to the bulk samples.

According to CMT results, 4% of the animals gave a score of 3, 6% had a score of 2 but an overwhelming number (92%) of animals remained negative. In the boiling test, 12% of both udder and bulk milk samples clotted. Similarly, the alcohol precipitation test gave a high positivity in milk collected at both stages, indicating low sensitivity of these tests. In samples positive for CMT, the SCC ranged from 1.4×10^6 - 12.7×10^6 . Milk from the receptacle had a very low SCC. Conversely, the total plate count (TPC) of the bulk samples gave an average of 2.5×10^5 in farm A and 4.35×10^5 in farm B, while the udder samples had a mean bacterial count of 1.3×10^4 .

Table 2. The mean total plate count (TPC) of bulk milk samples, the somatic cell count (SCC) of the udder milk samples and the California mastitis test (CMT) reaction of animals in Farm A and Farm B.

Farm	TPC (bulk)	SCC (udder)	CMT +ve
Farm A (25)	2.5×10^5	1.4×10^6	1
Farm B (25)	4.35×10^5	6.6×10^6	3
Mean $\pm$ SEM (50)	3.45×10^5	5.65×10^6	4 (8%)

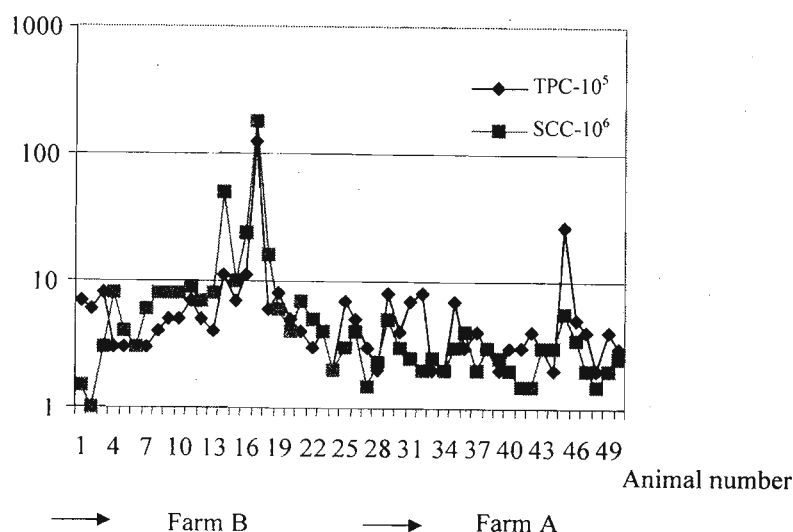


Figure 2. The total plate count of bulk milk samples and somatic cell count of udder milk samples in individual animals.

Figure 2 indicates the individual TPC of the bulk samples and SCC of the udder samples. In Farm A buffaloes with high SCC showed high TPC despite proper cleaning processes. Buffalo milk from both these farms was used in curd preparation. Fifteen per cent of the samples from the farm B indicated the presence of spore forming *B. cereus*, a heat resistant bacterium that is capable of contaminating curd. Moreover, 40% of the samples from this farm showed contamination with coliform bacteria, which were however destroyed by heating.

Discussion

Dye reduction tests are commonly used world-wide to evaluate milk for bacterial contamination (AOAC, 1980; IDF, 1986; Berg, 1990, Luke, 1991). The resazurine and the Methylene blue reduction times (MBRT) are both suitable tests to assess the keeping quality of milk, as they directly measure bacterial activity, require less skill to perform and are cost-effective. However, there are few disadvantages of these tests. For instance all bacteria may not show similar reducing qualities and some bacteria under tropical conditions may increase the pH of the media, but may not reduce the dyes. Further, if the SCC is high the reducing time is very short in spite of farmer handling milk with much care (Rook, 1979). The most reliable results are obtained only through serial sample analysis, which is time consuming and less practical under field conditions. The results of this study indicate that in terms of sensitivity, cost effectiveness and efficiency, the MBRT is the most suitable as a test to assess milk in order to remunerate on quality at the farm gate level. Although resazurine test is less time consuming it is less reliable and requires additional apparatus such as a Lovibond comparator.

The conventional alcohol test is a quick method to assess milk quality at the farm-gate level but is less sensitive. Unlike with the cow milk, 68% alcohol test is not suitable for buffalo milk as the higher protein content interferes with the test and may yield false positive results (Horadagoda, 1990). The titration methods to assess acidity is cumbersome and requires skilled personnel. The

boiling test although easy to perform is not quantifiable to be used in a scheme for remuneration of hygienic quality.

The Total Plate Count (TPC) is a good test to evaluate contamination though it is time consuming and expensive. The TPC is intended to reflect closely the total number of bacteria present in the sample. However, not all bacteria present in the sample may form viable colonies on a standard agar medium under specific incubation conditions. Further microorganisms, in groups may form one colony thus giving a false negative answer. In addition to the dye reduction tests, it is important to analyse specific bacteria like butyric acid bacteria and other heat resistant bacteria which may interfere with products such as curd, cheese or ready to drink milk.

This study clearly shows (Figure 1) that milk is subjected to high degree of contamination after being drawn from the udder and the need to increase the awareness of the farmers to produce better quality milk for which increased remuneration is provided. If hygienic quality is considered as a criteria for remuneration, it is important to analyse milk at the farm gate level, rather than as a collecting centre bulk sample which is analysed several hours later. The latter would include contamination in transit and other factors such a break down of a continuous cooling system which will not reflect the actual quality of milk from individual farmers and they could be unfairly penalised.

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SELECTION OF LACTIC STARTER ORGANISMS AND PERMITTED PRESERVATIVES FOR CURD.

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Abstract: Curd is a fermented milk product, where coagulation is brought about through the activity of *Streptococcus lactis*, *Streptococcus diacetylactis*, *Streptococcus cremoris* singly or in combination with *Leuconostoc* species. In Sri Lanka, most producers and consumers face problems relating to marketing and consumption, due to the poor quality of curd resulting from the use of either sub-standard hygienic procedures, a high microbial counts in milk or the use of improper starter cultures or a combination of all three factors.

To address these problems two separate studies on (a) starter cultures and (b) preservatives in use in curd production were carried out. Lactic starter organisms, isolated from 10 different marketed products of curd available in Kandy, were identified based on their cultural, morphological and biochemical characteristics. Of a total of 16 *Streptococci* species, 23 *Lactobacilli* and *Leuconostoc* species identified, 2 (isolates of) *Streptococcus lactis*, 2 of *Streptococcus thermophilus*, 5 of *Streptococcus cremoris*, 2 *Lactobacillus bulgaricus* and 5 *Leuconostoc* species were selected based on their rates of lactic acid production, clotting time, physical and organic properties, to formulate starter cultures for curd production. The starter culture combination comprising *Streptococcus cremoris* and *Leuconostoc* species was selected as the most acceptable formulation in the sensory evaluation, when the results were analysed by Friedman's non-parametric test.

The effect of incorporation of permissible preservatives for dairy products namely sodium benzoate and sodium sorbate at the rate of 0.1%, 0.2% and 0.3%, on the shelf-life of curd was examined, when stored at room temperature (RT) and a refrigeration temperature of 10°C, and with and without treatment of clay pots being with chlorine. Sodium sorbate when added at 0.2%, extended the shelf life of curd in clay pots treated with chlorine up to 5 days when stored at RT. The shelf life was even better when it was stored at the refrigerated temperature for 7 days. When plastic pots were used, the shelf life was extended up to 10 days at RT and 14 days at the refrigerated temperature.

Keywords: Curd, starter cultures, shelf life

Introduction

The preservation of food by fermentation is one of the oldest methods known to mankind. A typical example is lactic acid fermentation, which is widely used in the manufacture of dairy products. Curd is a popular and highly nutritive fermented dairy product in Sri Lanka, the use of which has been reported as far back as in 167 BC during the reign of King Dutugemunu (Pathirana *et al.*, 1996).

Curd is defined as the product obtained by coagulation of cow or buffalo milk or a mixture thereof through the agency of *Streptococcus lactis*, *Streptococcus diacetylactis*, *Streptococcus cremoris* singly or in combination with *Leuconostoc* spp. (Sri Lanka Standard 824, 1988). However, no well defined lactic starter cultures are used by the producers mainly due to the following factors. Firstly, they are not aware of the importance of the role of the starter cultures and secondly, they rely on the experiences gained through traditional practices followed by generation after generation. As a result, producers use as lactic starter culture, curd either from a pot of curd purchased from the market, or from the product previously produced by them, or yoghurt. This practice results in sub-standard products with a short shelf life. The Sri Lanka standard for curd permits incorporation of sorbic acid as a preservative at the rate of 1000 mg/kg. The objectives of this study were (1) to provide a lactic starter culture, in freeze dried form, to producers, which would result in an end product that would satisfy the consumer and (2) to

determine the optimum level of preservatives that could be added in order to obtain a better product with a longer shelf life.

Materials and Methods

Isolation and identification of lactic acid bacteria

Ten different commercially available products of curd were collected from the Kandy market. These were subjected to microbiological examinations in order to isolate the lactic acid bacteria. The procedures of Harrigaan and Mc Cance (1993) and de Man, Rogosa and Sharpe (1960) were followed. Dilutions of curd products up to 10^{-3} were inoculated and characteristic colonies on special media, MRS and M17 agar (Terizaghi and Sandins, 1995) were subcultured and identified according to standard bacteriological procedures as described by Buchanan and Gibbons in Bergey's manual (1975). The identified isolates were stored in skimmed milk.

Selection of cultures

- (a) Bacterial cultures from among the stored isolates were selected for the study based on the following criteria. Survival efficacy, clotting time, rate of lactic acid production, better growth on artificial media and in fresh milk.
- (b) Characteristics of the mixed cultures prepared from the selected isolates such as clotting time, pH, rate of lactic acid production, smell, whey separation and firmness of the curd were studied.

Evaluation of the quality of curd produced by use of selected mixed cultures

Curd prepared by the incorporation of selected lactic acid bacteria in mixed cultures were evaluated for their organoleptic properties (smell and taste) physical characteristics (texture and appearance) and chemical properties (pH and acidity). The parameters such as smell, taste, appearance and texture were assessed through a questionnaire given to members of a taste panel comprising 20 panelists. Every member was requested to submit their answers numerically using a scale ranging from 1-9 using a 9 point hedonic scale for computational purposes. The scores were analyzed using the Friedman's test. The pH of curd was checked with a pH meter, while the acidity was calculated following titration with 0.1 N NaOH.

Determination of optimum levels of permitted preservatives

Two preservatives recommended for dairy products, namely Sodium benzoate and Sodium sorbate were incorporated into the curd mixture prepared with the selected lactic starter organism combination at 3 different rates of 0.1%, 0.2% and 0.3%. Curd prepared in this manner was stored at RT and at +10°C, along with a control with no preservative added and tested daily for the keeping quality.

Effect of treatment of clay pots with "hypochlorite"

The curd mixture prepared using the selected lactic starter organism combination along with the preservative at the best selected rate was poured into clay pots treated with a solution of calcium hypochlorite (200 ppm). Treatment of pots was carried out on the previous day by dipping them in a solution of calcium hypochlorite for 30 min and then drying in an oven at 160°C. Curd prepared in this manner was stored at RT and at +10°C and tested for the keeping quality. Curd prepared as above was also allowed to set in plastic pots and stored at RT and +10°C and tested daily for the keeping quality after storage at RT and +10°C.

Results

Isolation and identification of lactic acid bacteria

A total of 39 lactic acid bacteria were isolated on special media i.e. M₁₇ and MRS agar from the 10 curd samples tested. Sixteen isolates were recovered in pure form on M₁₇ agar and 23 on MRS agar. *Streptococcus lactis* (2), *Streptococcus cremoris* (3), *Streptococcus thermophilus* (2), *Lactobacillus bulgariars* (2) and *Leuconostoc* spp (5) were identified and confirmed using biochemical tests. The 16 isolates which showed variable results in biochemical tests were not considered for further testing.

Selection of cultures

The two isolates of *Streptococcus lactis*, one of *Streptococcus cremoris* and 4 of *Leuconostoc* spp. showed acceptable values in production of lactic acid, pH and growth on artificial media as well as in fresh milk. Hence these were selected for the preparation of mixed cultures. These were mixed 1:1 by volume with either of the 4 *Leuconostoc* spp. *Streptococcus thermophilus* or *Lactobacillus bulgaricus* as suggested by the Sri Lanka Standards thus resulting in 18 different formulations.

Table 1. The clotting time, the pH and the percent of lactic acid formed by mixed cultures

Formulate Number	pH (6hr)	pH (24hr)	% of lactic acid formed		Clotting time	
			6 hrs after inoculation	24 hrs after inoculation	at 37°C (h)	at RT (h)
1A	5.0	4.2	0.56	2.90	2	4 ½
1B	4.2	3.6	1.36	3.30	2	3
*1C	5.3	4.8	0.38	1.05	4	7
*1D	5.1	4.5	0.32	1.20	4	6
1E	4.9	4.8	0.34	0.54	2	2
1F	5.1	4.7	0.34	0.72	2	3 ½
2A	6.1	4.7	0.12	0.68	1	2
2B	4.3	4.3	1.42	2.81	2	4 ½
2C	4.3	4.2	1.40	2.84	3	3
2D	4.0	4.0	1.60	2.98	3	4 ½
2E	5.2	4.6	0.29	1.17	5	6 ½
2F	5.3	4.4	0.46	2.60	3	4 ½
3A	3.8	3.4	2.25	3.50	1	3 ½
3B	4.2	3.8	1.43	3.05	1	3 ½
3C	4.7	4.4	0.50	2.63	3	4 ½
3D	4.0	3.6	1.57	3.30	2	4 ½
3E	5.0	4.3	0.54	2.80	2	3 ½
3F	5.1	4.4	0.47	2.60	3	2 ½

As indicated in Table 1, based on the pH, titrable acidity and curdling efficacy 3 formulations namely 1C (*Strep. lactis* 2, *Leuconostoc* spp 4), 1D (*Strep. lactis* S2, *Leuconostoc* spp) 2 and 2E (*Strep. cremoris*, *Leuconostoc* spp 3) were selected for curd production. The clotting time of 1C, 1D and 2E at 2 different temperatures (37°C and RT) were within 4-7 hours. When compared to these cultures other formulations indicated shorter clotting time periods. As the pH reduces with time (i.e. acidity increases) they were not selected for curd product.

Evaluation of the quality of curd produced by selected mixed cultures

The probability value and sum of ranks given by 20 panelists for the appearance, smell, taste and texture for the 3 different types of starter cultures used to prepare curd are given in Table 2.

Treatments 1, 2 and 3 are the synonyms for the curd prepared incorporating the 3 selected starter culture formulations IC, ID and 2E respectively.

Table 2. Results obtained by the Friedman non parametric test

Treatment	Sum of ranks			
	Appearance	Smell	Taste	Texture
1(A)	31.0	35.0	41.5	35.0
2(E)	39.0	35.0	26.5	32.0
3(F)	50.0	50.0	52.0	53.0
Probability value	0.009	0.010	0.000	0.000

* Treatment effect is highly significant at $p = 0.05$

From the results of the analysis it is evident that the preference to appearance, smell, taste and texture is significantly different among the 3 products. The product 3 (2E) achieved the highest rank in all 4 characters. Therefore among the 3 products, curd 3 was the best. When compared to product 2, curd 1 has a higher acceptance.

Detection of effective level of permitted preservatives

Figures 1 and 2 indicate the keeping quality of curd prepared incorporating sodium benzoate and sodium sorbate respectively at different strengths (0.1, 0.2, and 0.3%). Sodium sorbate was found to be the best preservative to increase the shelf- life to 5 days at the rate of 0.2% and stored at $+10^{\circ}\text{C}$. However, both preservatives acted in the same manner when curd was stored at RT (Fig. 1 and 2) where the shelf life was 4 days. Yeast and moulds were found to be the major causes of reducing the shelf life of curd.

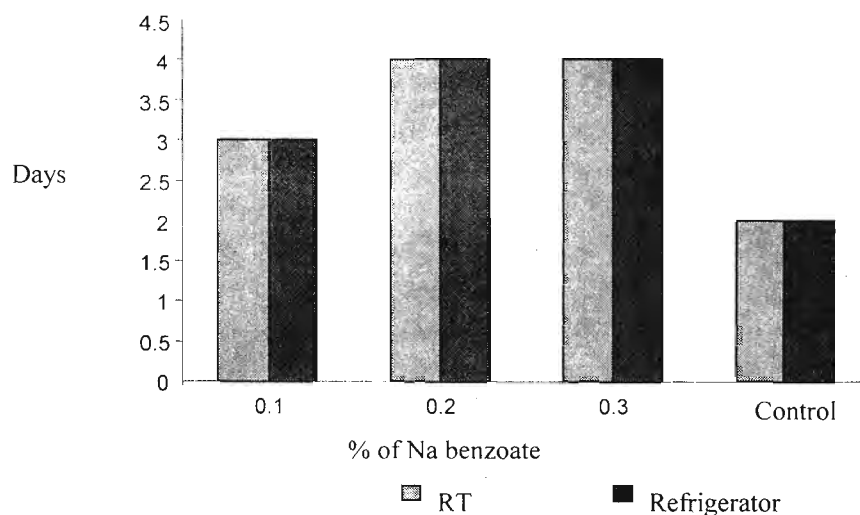


Fig. 1 Keeping quality of curd with different percentages of sodium benzoate

Effect of treatment of clay pots with hypochlorite :

The shelf life of curd was extended up to 7 days when the mixture with (0.2%) sodium sorbate was allowed to set in clay pots previously treated with a solution of calcium hypochlorite and stored at $+10^{\circ}\text{C}$ (Figure 2). In plastic pots the curd prepared using the same procedure was found to be satisfactory up to 10 days at RT and 14 days at $+10^{\circ}\text{C}$.

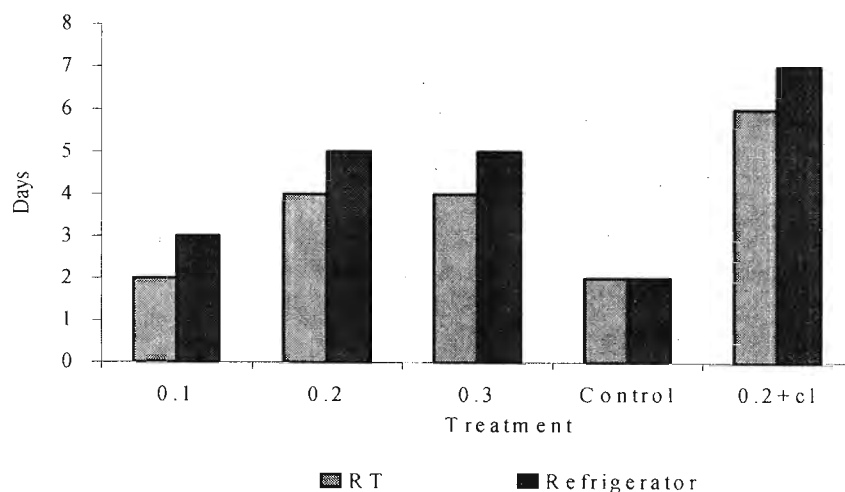


Fig. 2 Keeping quality of curd with different percentages of sodium benzoate

Discussion

Important factors that determine the quality of curd are the level of microbial contamination and the quality of lactic starter culture used in the fermentation. A study carried out on “Ruhunu” curd revealed the presence of coliforms and *E.coli* indicative of poor hygienic standards (Pathirana *et al.*, 1996). In order to improve the hygienic standards the authors suggested that the farmers be encouraged to adopt simple methods and technology involving minimum interventions. Nearly all those who are engaged in the production of curd are not aware of the importance and the role played by the starter culture.

The present study was undertaken with a view to improve the quality of curd by supplying a starter culture and by determining the optimum level of permitted preservatives that could be incorporated. The lactic acid bacteria that were selected and incorporated in a formulation comprising *Streptococcus cremoris* and *Leuconostoc* spp is now available for farmers in the lyophilized form. The combination of these two organisms is in agreement with the Sri Lanka Standards, (1988) 824 Part 2. The starter culture described here is distributed among producers through the Government Veterinary network in the country.

Spoilage of fermented dairy products is initiated by fungal growth due to low pH and growth of spoilage bacterial/ flora commence as the pH of the fermented product gradually rises during mould growth (Jay 1996). During this study too, fungi was visible on day 2 when no preservative was added, while bacterial contaminants were not detected throughout the study period.

Use of sodium sorbate at the rate of 0.2% along with the practice of treating clay pots with hypochlorite (200ppm) prior to use can substantially increase the keeping quality of curd. The shelf life of curd prepared in this manner in plastic pots was extended up to 10-14 days, however indiscriminate use of plastic pots could lead to an environmental hazard.

The objective is to improve the quality of the curd by supplying the starter culture and providing recommendations on preservatives and treatment of pots. In conjunction there should be programmes for farmer education on hygienic procedures of curd production.

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SYMPOSIUM - VII

Product Technology and Economics

Discussion

Q. C.M.B. Dematawewa - If the value for elasticity is over 1, how do you interpret this results?

A. C. Bogahawatta - If the elasticity of milk and milk products is over 1, it means that its price is elastic. That is, if the price of milk and milk products increase by 1%, the demand for milk and milk products will increase by over 1%. Generally the price elasticity of milk and milk products in Sri Lanka is inelastic and in India it is elastic. This means that the Indian consumers are more price responsive when compared to Sri Lankans.

Q. A. Horadagoda - The study showed that nearly 40% of the customers consumed curd. Is it because the study was conducted in the Kurunegala District?

A. C. Bogahawatta - Yes, it is very specific to the Kurunegala District which is an ideal area for curd production due to the intensity of milk production and higher buffalo and cow populations. This situation may not be the same in other districts.

Q. H.V.R. Navaratne - The price of milk is different in India compared to Sri Lanka. Will this affect the elasticity values?

A. C. Bogahawatta - No. The price elasticity is an index measure. It is not affected by the scale of measurement.

Q. H.V.R. Navaratne - Does the availability of liquid milk to meet the demand affect this study?

A. C. Bogahawatta - Yes. The demand for liquid milk may be low, as it is low in supply in most of the urban areas and even in rural areas. The consumers also prefer powdered milk as compared to liquid milk. If the demand for liquid milk is to be increased, the attitude of the consumer towards liquid milk has to be changed.

Q. O.P. Dhanda - Is the figure of six litres, the per capita consumption?

A. C. Bogahawatta - It is the per capita consumption per day.

Q. C.B. Salces - In the Philippines, we identify impact zone areas, because not all farmers like AI. In the impact areas, we go to the farmers who are responsive to technologies. For example, if you want to promote AI, you look for a fodder farmer, because he will be willing to use new technologies. We introduce technologies in these impact zones without trying to provide services everywhere.

A. S.H. Raza - The setup is different in different countries. We have provided good AI service centres, but the problem is with the staff. If the staff are not there, farmers will resort to natural service, and we do not get a return on investments. If we can place bulls in each village, we can improve the animals.

Congress Workshop

The Organising Committee included a Workshop as part of the Congress activities so as to take advantage of the presence of eminent resource persons who will attend the Congress and provide an opportunity for field Veterinarians and livestock extension personnel to discuss some of the priority issues that confront them in their field activities. The theme of the workshop was "Cattle and buffalo farming: - Technical, marketing and trade issues". The workshop which was held at the Kandalama Hotel on the 30th March 2000 commenced at 9.45 am and continued till 4.00 p.m. Session I dealt with aspects relating to nutrition, reproduction and health, while Session II was devoted to discussions on marketing and trade.

The moderators of the workshop were Dr. B.M.A.O. Perera and Dr. M.C.N. Jayasuriya. The discussion that followed the lecture presentation was lively and profitable. The participants appreciated the efforts of the organisers in arranging the workshop which was considered a success. The detailed workshop programme is given below.

The workshop was sponsored by Agro-Enterprise Development Project through the initiative of the Sri Lanka Association of Animal Production.

Session I

Use of commonly available feed resources in ruminant feeding – limitations, methods of overcoming limitations, and feed formulation

M.C.N. Jayasuriya

Minerals and vitamins in ruminant nutrition – mineral and vitamin deficiencies, their significance on health, production and reproduction and methods of overcoming deficiencies

S.S.E. Ranawana

Infertility in buffaloes and cattle – diagnosis and treatment

M.R. Jainudeen

Use of hormones in the control of reproduction in cattle and buffaloes

B.M.A. Oswin Perera

Epidemiology, diagnosis and control of common bacterial and viral diseases of cattle and buffaloes in Sri Lanka

S. Kodituwakku, T.G. Wijewardena, N.U. Horadagoda and R. Hettiarachchi

Common parasitic diseases in cattle and buffaloes – treatment and control

D.J. Weilgama and R.P.V.J. Rajapakse

Session II

Food security, free trade and trade agreements and ways to cope with free trade

N. Sandaratne

Marketing of livestock products from farm –gate to the consumer – methods of reducing marketing margins, horizontal and vertical integration and matching consumer preference

C. Bogahawatte

Field Excursion:

An opportunity was provided to foreign participants to gain first hand information on buffalo production and management practices at the field level. The field visits included the buffalo farm of the National Livestock Development Board (NLDB) at Melsiripura located at a distance of about 65 km north of Kandy. They were accompanied by a few of the local scientists. This is a large state farm located in the dry intermediate zone in Kurunegala district, which maintains a herd of Surti buffaloes imported from India. The farm provides breeding animals to farmers who prefer to rear a dual purpose buffalo. The participants also visited a few smallholder buffalo farms in the Melsiripura and Dambulla areas. This gave the visitors an opportunity to observe and study the buffalo management practices at large and small farm levels in the traditional buffalo rearing area of the country.

The foreign participants were in addition given an opportunity to see the Sigiriya rock fortress, which is one of the treasured cultural monuments of ancient Sri Lanka. The site displays the world famous 5th century rock paintings (Frescos), the hydrological engineering and other advanced town planning feats of Sinhala kings of that period. The foreign scientists also visited the Dambulla rock temple, a historic, cultural and religious centre, which contains many ancient paintings and statues of Buddha dating back to the 5th century. At the conclusion of the field tour, the foreign participants joined the local scientists at lunch at Kandalama hotel.

Conclusions and Recommendations of the Third Asian Buffalo Congress

The Organizing Committee of the Third Asian Buffalo Congress recognising the importance of the Congress provided time on the final day to focus on the application of recent advances in research and development of the buffalo in the context of the changing socio-economic conditions. Based on the valuable contributions that were made by the participants, a set of conclusions and recommendations giving guidelines for research and development of the buffalo were formulated to meet the future needs of the countries in the Asian region in the new millennium. Although it is customary for international meetings of this nature to present recommendations at the conclusion of the deliberations, this Congress gave special attention primarily to the need to provide guidance not only to scientists but also to national governments in the Asian region for consideration in drawing up strategies relevant for future research and development activities relating to the buffalo.

The discussions were focussed on the priority development needs based on the current information and experiences of the participating scientists, both local and foreign. This session was moderated by Dr. B.M.A.O. Perera of the Animal Production and Health Division of IAEA in Vienna and who is also the out-going Vice President of the Asian Buffalo Association.

The discussions were taken up under eight major areas of buffalo production that are of great relevance to the Asian region, namely: 1) Production systems, 2) Genetics and breeding, 3) Reproduction, 4) Nutrition, 5) Health, 6) Biotechnology, 7) Product technology and economics and 8) the vision for the future. The conclusions and recommendations are given below under each of the above heading.

Production Systems

Conclusions

Production systems are changing towards milk and meat oriented system and in response to changes in socio- economics.

Smallholder farming systems continue to be important.

Recommendations

Emphasis is needed on buffalo integrated small farm systems, as a dual/multi-purpose animal.

Compiling and dissemination of available information.

Attempts should be made to reverse the declining trend in the buffalo population.

Genetics and Breeding

Conclusions

Full exploitation of the buffalo has not been realised.

Breeding policies are not fully implemented in many countries of the region.

Recommendations

Action needed to conserve, evaluate and preserve buffalo genetic resources.

Breeding policies should be formulated/reviewed/updated where needed and implemented.

Selection programmes should be implemented for genetic progress.

Traits such as behaviour, temperament, reproduction, heat tolerance in addition to those related to milk, meat and draught, should be taken into consideration in the selection process.

Reproduction

Conclusions

Reproductive efficiency is generally low, manifested as long post-partum anoestrus and long calving intervals. The main causes are poor nutrition and management, including inefficient heat detection, inappropriate suckling management and lack of selection.

Lack of breeding bulls has been a major constraint.

Recommendations

Artificial Insemination coverage should be increased.

Evaluation of bulls should be performed by Open Nucleus Breeding System

New technologies need to be translated to field applications and combined with information dissemination.

Nutrition

Conclusions

Buffalo feeding will continue to rely on low quality feeds.

The supply and quality of feeds are limiting, resulting in underfeeding.

Recommendations

There is a need to optimise the utilisation of local feed resources and develop appropriate feeding strategies.

Research is needed on underlying physiological processes which give comparative advantage to buffaloes.

Health

Conclusions

Calf mortality continues to be a limitation.

Current vaccines for Haemorrhagic septicaemia (HS) need further improvement.

Infectious causes of reproductive failure limit productivity and prevent trans-boundary movement of genetic material.

Recommendations

Studies are needed to investigate the causes of calf mortality and minimise the problem.

Apply biotechnological methods for better diagnosis and improve vaccines (particularly HS vaccine).

Each country must implement national measures for controlling reproductive diseases.

Biotechnology

Conclusions

Biotechnology(BT) has a great potential for increasing buffalo productivity in fields such as genetics, reproduction, nutrition and health.

Existing biotechnologies are not efficiently used.

Recommendations

Biotechnology research and development should be supported.
Existing BTs need to be further developed and adapted to current needs.

Product technology and economics

Conclusions

Some countries have made excellent progress in linking production with marketing.
Adequate methods to assess the hygienic quality of animal products are lacking.
Cost of production is continually increasing.

Recommendations

Sharing of expertise in product technology within the region is a must.
There is a need for vertical integration of production, processing and marketing.
Methods for matching cost of production to consumer prices should be found.
Develop technologies to optimise by-product technology.

Vision for the Future

The buffalo will grow in importance as a livestock resource for most tropical Asian countries.
There is a need to exploit the comparative advantage of the buffalo to utilize marginal lands and other resources for production.
Mobilise Information Technology for promoting buffalo production.
Transfer of technology and effects on environment.
International Institute should be established in Asia to conduct research and focus on the development of buffalo production.

Address By Dr. R.O.B.Wijesekera

*Chairman, National Science and Technology Commission (NASTEC)
Former Special Technical Adviser, UNIDO, Vienna, Austria*

Mr Chairman, distinguished delegates, ladies and gentlemen. Permit me to begin by thanking the organising committee for inviting me to deliver this closing address at this Third Asian Buffalo Congress. I feel it is an honour and I must confess that I accepted this invitation with some degree of avidity, for I wished to share some of my thoughts regarding my present preoccupation, in my capacity as the Chairman of the National Science and Technology Commission, with a local as well as an international audience.

Having had the privilege of working in several developing countries within Asia, Africa and Latin America, I do know that some of the problems of science and technology in the developing world bear common characteristics.

Permit me first to tell you that the National Science and Technology Commission (NASTEC) is the designated apex body for Science and Technology in this country. It is a recent creation by an Act of Parliament, which was only implemented a year or so ago. Among its many functions is to enhance and safeguard the National Science and Technological capability. One of the priorities is to work towards the building up of a virile and productive scientific and technological sector in this country. This is a long term exercise for which the steps must be taken forthwith, if we are to reverse the debilitating effects of the brain drain on our system. In moving towards this goal NASTEC has the mandated function to interact with both regional as well as international science to help the scientific culture of this country grow, and to help the scientific community in familiarising itself with the leading edge of science in the world, in a variety of topics of relevance to us. The cornerstone of the exercise is of course scientific research. Hence you would understand my interest in being here at this Congress just concluded. So, as the Chairman of NASTEC, I have not only an interest but also a function to perform to encourage the growth of scientific knowledge in this country. For let it be clearly stated: it is today's knowledge that gives rise to the technologies of tomorrow.

Having listened today to some of the presentations at this Congress, I am struck by the fact that this exercise exemplifies two very significant aspects of the growth of science., which to me are of the greatest importance. One is the accumulation of knowledge by research, and the other of the sharing of that knowledge with peers who are both national as well as international. This is the manner in which science has grown over the years. The creation of a **Research Culture** leads to the formulation of a knowledge base within a country in the subject areas of the research. International interaction gives the scientific personnel an acquaintance with leading edge research in the relevant field of work. The international personnel who work in specific areas and who interact with each other are sometimes known as the "invisible colleges of science".

In the creation of a knowledge base, one first of all builds up clusters of research activity in such fields as are relevant to the country. These are fields that the decision makers would feel obliged, on account of their social relevance to the country, to invest funds in. These clusters develop in numbers until they form a significant body of knowledge which forms the research or knowledge base of the country, and the ability to interact with leading edge research worldwide.

To an organic chemist like myself, there is a close analogy here, to the phenomenon of crystallization. Those who are chemists will know that crystallization occurs with the formation of one or more clusters of crystals, which then develop to many more in number, until the base of the vessel is eventually fully covered. Likewise, if we begin an intensive research programme with a single subject area and extend this capability along the many disciplines that are needed for this research area, we may be building a significant research capability. This is the manner in which

science grows. As I said, the growth of science is strikingly analogous to the phenomenon of crystallisation. It has been the case through history and it is the same whatever be the subject area. Now when as I said, science grows along a number of disciplines, then that is the forerunner to the development of a scientific and technological capability within a nation.

The second important illustrative feature I mentioned that this congress exemplifies is that of international interaction. Science within a country cannot grow in isolation. It has to interact with leading edge knowledge bases wherever they exist. This process is what I referred to as the "invisible colleges of science". This means that in each subject area, there is a kind of relationship such as you have among yourselves now, a relationship of common interests in a given scientific area of activity. So this exercise just completed is of particular significance as it is the means by which an endogenous scientific capability can be built.

The subject of your congress has also been of interest to me in a somewhat peculiar way. Recently I had the good fortune to enjoy a holiday at the National Reserve at Uda Walawe. I could not help but observe the many buffaloes gathered there during the day time. It seemed like a ritual that the least observant among us could not help but observe. They would come in at about two o'clock in the afternoon each day. By half past two the entire community of buffaloes were gathered by the lake side, seemingly for their daily get-together. They do everything there. They bathe, they wallow in the mud, they fight each other, they guard and train the young, they even copulate! At about five in the evening, invariably following some signal from the leaders they commence leaving in remarkably orderly fashion. Then on one day I observed they began leaving rather earlier than normal. And when we continued to wonder, the reason soon became obvious. Because no sooner had all the buffalo herd disappeared, troops of elephants began to come towards the same lake for their enjoyment of the water. So the buffaloes and their leaders having known this, had slowly marshalled their herd and peacefully left in time.

Now to us, who belong to a tradition where the buffalo is demeaned, where if you wish to insult somebody you remark that the person is like a buffalo, this orderly pattern of behaviour appeared strange. It seemed that the buffalo was far more orderly and disciplined than the folk we see in any one of our capital cities in this region. They came in and exited in impressive fashion. After that, I had a healthy respect for the buffalo from whom humans could take many lessons. I am certain you who have researched on this subject will agree.

So to come back to the subject that I was talking about earlier, you may well ask me, why build up a capability in science and technology. Wherefore this need? And my answer to this question is the following. Analogous to what was once told me by a very great scientist, "you should have brains to pick brains"; you have to have the knowledge in order to understand what is going on in the world. Today, it is important that all of us have some of this scientific and technological knowledge, not only because we would then be able to understand what is going on in the world, but, mark you, because of the dangers that can arise by not understanding what is going on in the world around us. I don't have to tell you about the hazards caused by the dumping of nuclear waste, of chemical residues in foods. Nor have I to elaborate to an audience like yourselves the dangers to our third world agrarian systems, had Monsanto's "terminator gene" been allowed to go unchallenged. It is because some of our countries possessed the required knowledge, that they were able to avert what would have been a third world disaster. So it is important that scientific activity prevails in every country, at the frontiers of science where needed.

There are reasons why we should be knowledgeable in the areas of science that is important to us. In today's context therefore building a science and technology capability in a country is no longer an option. It is a necessity.

During the course of this morning, I have listened to presentations that impinged upon several disciplines, such as chemistry, food science, biotechnology etc. I began to visualise, that given the importance of the context of research on the buffalo, the interest within this country and the

international arena, the buffalo would be a good subject to commence a major research thrust, in this country. It is certainly one which would lend itself to building up research activity in several significant areas.

Now you may yet wonder why I place so much significance in the building up of a research capability within a country, not only this country but for that matter any developing country. Developing countries are those that by the nature of things suffer from a weak science and technological infrastructure. They are those that are less able to support a vibrant research activity, and hence have to be selective in their investments on science and technology.

I may digress here now, to tell you something more about the responsibilities of NASTEC as the apex body for science and technology in this country. We are, as I stated, the overall apex advisory body for science and technology in the country. However I must emphasise that we are not another bureaucracy. The Commission consists of six scientists and the chairman appointed by the President of the country. The support base of the Commission is the entire scientific community of the country. We draw on their expertise and services as required.

Our present initiatives include the drawing up of a Science and Technology Agenda for National Development (STAND). We are to do this by way of a unique biennial conference on Science and Technology (BICOST I), which we are mandated to hold later this year. At this conference the participating scientists, a representative selection, will develop the future outline of the STAND which will then be presented for implementation to the President.

The development of a science and technology capability within the country is of crucial importance, and hence our priority consideration? There are several reasons for this, in addition to those I have mentioned before. In the context of the globalised economic order of the day, the dice is loaded against the developing countries, particularly those with small populations and little natural resources like Sri Lanka. They have to compete with all the disadvantages of a weak science and technology infrastructure on a level playing field with the industrialised world. So the stronger the capability the better will be the prospect of survival. Their products will have to compete at international level. Hence we should gear ourselves to be able to absorb the benefits of international science as relevant to the case, develop competitiveness of our products and services, be able to determine the safety and efficacy of products introduced from outside and be able to benefit from a knowledge of the dangers of some of the new developments.

In Sri Lanka unfortunately, since independence we as a nation have neglected the investment to develop our scientific base and hence the necessary infrastructure. We have not taken the example of neighbouring India, where the visionary Jawaharlal Nehru laid the foundation for the impressive Indian scientific capability of today. Our science and technology on the other hand is decreescent, from continued under investment. We have our human resources depleted by the migration of scientists away from the land of their birth. And in the context of today, there is no significant interest or investment by our private sector.

So, one of the functions of NASTEC is to address this issue. We have to spring a vivid dialog with the Government as well as the Private sector and initiate action to remedy this unsatisfactory state. One method of such a dialog would be the mandated biennial conference (BICOST I) that I referred to earlier. We have to ensure that both government and the private sector act as partners to nurse, revive, and invigorate our scientific infrastructure and move towards the development of greater capability. We have also commenced some initiatives with a USAID consultant in sensitising the business sector to the fact that a strong science and technological set up will be to their own advantage as well.

I am therefore uncompromising in my belief that the country should be committed to putting science and technology, innovation and design, at the core of our thinking and action if we have the desire to survive in the new millenium as a nation with an acceptable standard of living.

So I see the staging of international events such as the Buffalo Congress just concluded, as an example of the necessary catalytic activities to bring about the desired thrust to science and technology. As I remarked before, the two things necessary for a country's science to thrive are these: interaction within the peers of the subject area, and a national commitment to develop a knowledge base.

I am grateful for the opportunity to address you and share my thoughts with you. I congratulate the organizers on a successful venture and from our side I hope that this Congress will serve as a seed for the growth of a much wider scientific knowledge base in this country, from which we will be able to contribute even more to future congresses that you will surely have.

Thank you.

Author Index

Abeygunawardena, H.	367	Merca, F.E.	209
Abeynayake, P.	143, 273	Misra, A.K.	299
Abeysekera A.W.A.S.	347	Moioli, B.	37
Alboghobeish, N.	237	Noordeen, F.	263
Alexiev, A.	17	Oshibe, A.	219
Aquino, F.P.	331	Pabuayon, I.M.	209
Ariff, O.M.	219	Paranagama, D.M.	147
Atapattu, N.	353	Pathirana, K.K.	337
Bandara, B. H. W. M. U. S.	93	Pedro, P.B.	331
Bogahawatte, C.	383	Perera, A.N.F.	183, 241, 359
Borghese, A.	37	Perera, B.M.A. Oswin	227
Capitan, S.S.	209	Perera, E.R.K.	183, 241, 359
Chandrasekera, D.M.S.K.	383	Perera, V.	353
Chandrasiri, A.D.N.	147	Premaratne, Sujatha	197
Chantalakhana, C.	1	Premasundara, Anura S.	367
Cruz, L.C.	85, 331	Rajapakse, R.P.V.J.,	263
Dangolla, A.	277	Rajaratne, A.A.J.	25
De Alwis, M.C.L.	55	Ranawana, S.S.E.	25
De Vera, R.	331	Ranjhan, S.K.	47, 75
del Barrio, A.	85, 331	Raza, S. H.	191, 393
Dematawewa, C.M.B.	129	Roxas, D.B.	209
Dhanda, O. P.	325	Salces, C.B.	85, 209, 331
Duran, D.H.	85, 331	Seresinhe, T.	337
Eskershall, P.D.	267	Shahani, S.K.	283, 291
Faizal A.C.M	263	Silva, G.L.L.P.	129
Fernando, P.S.	397, 403	Silva, I.D.	277
Gallage, S.S.	267	Singh, S.	325
Hayakawa, H.	219	Skunmun, P.	1, 63, 99
Hingpit, B.A.	209	Soomro, S.A.	283
Horadagoda, Ajantha	397	Sukri, I. Mohd.	219
Horadagoda, N.U.	263, 267	Sunil-Chandra, N.P.	255
Hufana, R.H.	331	Thalagoda, S.A.	267
Jainudeen, M.R.	81, 121	Teufel, N.	191, 393
Jayasuriya, M.C.N.	157	Thu, Nguyen van	105
Jayaweera, T.S.P.	347	Tripaldi, C.	37
Jude, J.A.	263	Ullah, A.	191, 393
Kachiwal, A.B.	283, 291	Vipulasiri, A. A.	273, 403
Kalhoru, A.B.	283, 291	Wan Zahari, M.	81, 219
Kalyanasundram, N.	403	Welagedera, D.	397
Kathio, I.H.	283, 291	Wickremaratne, S.N.	359
Khan, S.	191, 393	Wijewardana 'T. G.	267, 273, 403
Kulachelvy, K.	277	Yatawara, M.D.M.L.D.K.	347
Kundu, R. L.	325		
Lustria, E.M.	209		
Makkar, Harinder P.S.	167		
Masahiko, M.	331		
Memon, A.Q.	283, 291		

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EPILOGUE

The Buffalo

Nimal Sandaratne

You despise me
Call me ugly, foolish, dull.
My gaze,
You call a vacant look.

On muddy fields, I toil
To churn and prepare the soil
Your staple food to grow
And feed you more.

To tractors, I'm oft compared,
'Cause I work so hard
But on tractors you expend
On fuel, repairs and spares to mend.

You show no appreciation,
That I've no capital depreciation
Compared to tractor, I excel
As many more tasks I do as well.

When I bring forth my young
You wean and feed them less
Then you squeeze my udder
For milk and butter.

My milk in fat content
Is of a higher extent
So from it curd you make
And eat to your heart's content.

Now you want from me more milk
And research to find a trick
A dull unsavoury brick
Which makes me really really sick.

Why oh why must you deny.
My only natural joy
Your artificial insemination
Is devoid of any consideration.

To you scientists must I plead,
To have some compassion on my breed.
My mind is not so very dull
Nor my hide too thick.