Sun-drying Methodology

REPORT OF A SEMINAR
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NATIONAL SCIENCE COUNCIL OF SRI LANKA

REPORT

No 3-'76

A Seminar Discussion on

Sun-drying Methodology

Co-Sponsors :

National Science Council of Sri Lanka
Australian High Commission in Sri Lanka

National Science Council of Sri Lanka
Colombo, 1976

The Seminar was inaugurated by His Excellency, **Mr. A. H. Brothwick,** Australian High Commissioner in Sri Lanka and held at the Agrarian Research and Training Institute, Colombo, on the 21st May 1976.

C O N T E N T S

PREFACE

The report is the product of a Seminar sponsored by the National Science Council of Sri Lanka with the cooperation of the Australian High Commission. Mr. Donald McBean, Principal Food Scientist of the Commonwealth Scientific and Industrial Research Organisation, Australia, was the guest speaker. Several scientists from the University Campuses and Research Institutions participated in the Seminar.

The purpose of the seminar was to discuss problems of solar drying in Sri Lanka and to identify priorities for actual research in this field.

Solar energy will play an important role in the future as a source of energy for man's application. It is an energy source that does not add undesirable chemicals to the earth's atmosphere or water and does not exploit unrenewable resources. Sri Lanka has available good solar radiation. The intermittent nature of solar energy, however, results in problems of designing adequate levels of reliability into solar processes.

The final report is the edited collection of the lectures given during the seminar together with the discussions that followed. The recommendations made to the National Science Council have resulted from the pooled knowledge and experience of all the participants.

Mrs. Clodagh Fernando, Scientific Officer, was responsible for the arrangements regarding the seminar, which was held at the Agrarian Research and Training Institute. I wish to acknowledge with thanks the help of Miss Eleanor Jurianez, Scientific Officer, in the preparation of this report and Miss Sita Fernando for secretarial and other assistance.

Nimala Amarasuriya
(Editor)

National Science Council of Sri Lanka
47/5, Maitland Place,
Colombo 7.

October 27, 1976.

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INAUGURAL ADDRESS

His Excellency, Mr. A.H. Borthwick
Australian High Commissioner in Sri Lanka

My remarks will be very brief as it is more profitable for you to listen to Mr. McBean in the short time that is available.

The increasing population of the world necessitates the provision of a greater supply of food. This raises the question of the preservation of agricultural surpluses. One of the methods traditionally used to preserve surplus produce is drying of the material in the sun. The industry is extensive and practised on a world wide basis.

Food preservation and technology is of vital importance to Sri Lanka and so is the use of solar energy, due to the prevailing energy crisis. I hope that the information Mr. McBean brings would prove valuable to you and that we could look forward to further exchanges of scientific personnel in the future.

We are very obliged to the Commonwealth Scientific and Industrial Organization of Australia for releasing him.

INAUGURAL REMARKS

Dr. Osmund Jayaratne
Chairman, National Science Council of Sri Lanka

I would like to say a few words on behalf of the National Science Council of Sri Lanka which is sponsoring this seminar on "Sun-drying Methodology" in co-operation with the Australian High Commission.

We are fortunate to have today, Mr. Donald McBean, Principal Food Scientist of the Commonwealth Scientific and Industrial Research Organization. Mr. McBean at present is on a tour of Nepal, Thailand and Sri Lanka studying existing methods of solar drying and giving valuable advice on possible methods for future improvements in this field.

Mr. McBean, I thank you for being present with us today to discuss with us the pressing problems of solar drying in Sri Lanka.

I have great pleasure in calling upon Prof. Arthur Weerakoon of the Vidyodaya Campus to chair the proceedings.

INTRODUCTION

Chairman : Prof. A. Weerakoon

I consider it a great privilege to chair this very important meeting. Though I am not really a food scientist, I started the first and only post-graduate food science course in Sri Lanka, although I am an ecologist.

This seminar is very important because it is obvious today that we must produce more food. All the people who matter - scientists, economists, etc. are struggling in the toils of the myth of our century that we are multiplying too fast and therefore we are not eating well enough. But it is because we are not eating well enough that we multiply too fast! When people have enough to eat the birth-rate is lowered, as it happened in Russia. One day this problem will have to be tackled in the proper way- a more egalitarian distribution of food. I am perfectly aware of the fact that unless we have enough food and we preserve this food properly we would still be suffering from malnutrition. We must look for cheap and efficient methods of preserving food.

We, in the under developed countries, are great imitators of the more developed world. Attempting to imitate the more affluent countries can lead us into difficulties although occasionally we might benefit by following their methods. Even foreign scientists today are interested in simple unsophisticated technologies which could be adopted to suit our needs. Many local scientists have been struggling to develop local technologies. A gradual change of mentality of the younger generation should be encouraged. Over-emphasis on following the methods of the developed countries manifests itself in many ways, for example, overemphasis on foreign expertise. Thus, local scientists tend to be neglected to the detriment of the country.

I would be very useful if we end this seminar with a set of priorities for actual research.

Basic Principles of Drying Processes and Particular Features of Sun-drying Methodology

D. McBean

I will begin by giving a brief outline of how I came to be in Sri Lanka. In April 1975 a Seminar was held on behalf of the Association for Science Co-operation in Asia (ASCA) in Australia. Of the 22 countries belonging to ASCA, Korea, China, Papua New-Guinea and all the South-Eastern Asian countries were among those represented. The representatives were asked to define the most pressing problems in the under developed countries. By general consensus, three problems were outlined of which Sun-drying was considered the most important. It was then decided that an expert in this field would visit any of the 22 countries. Sri Lanka is the first step in my tour which will include Nepal and Bangkok. Later in the year, I will be touring Malaya and the Phillipines.

I am in the Division of Food Research and Technology at the CSIRO, Australia, and am responsible for the drying of fruits. When I came to Sri Lanka I was unaware that I would have to take part in a seminar. However, I am happy to have the opportunity of discussing with you the problems of sun-drying. I would like to make this discussion as simple and practical as possible.

All the basic information to be used in sun-drying methodology already exists. We know the energy pouring from the sun on the earth is 2 calories/cm^2/min. This is a colossal amount of energy. Our problem is how do we harvest and collect it. Is it possible to store it as the sun's energy supply is intermittent? The developed countries spend billions on research on the storage of solar energy.

The amount of power that can be stored in a solar absorber for the most part of the year in the tropics is 4.6 kilowatt hrs/m^2/day. The efficiency may be 20-25%. In the future it may be possible to make a more efficient solar absorber.

In Australia, we use sun-drying quite extensively, 400,000 tons of grapes are dried per year and all the energy comes from the sun. Artificial energy is only used during the rainy season. 20,000 tons of apricots, peaches and pears are similarly sun dried. Grain is dried in silos where the moisture content is lowered due to solar energy. A fan is operated when the humidity outside falls below the optimum value. This method is too sophisticated but large quantities of grain are dried in this way. Halved apricots are spread one-layer thick on wooden trays for drying in Australia. About 50% of their weight is lost in this way. The relative humidity is 20-30% and the temperature being in the range of 30-40°C. These conditions favour drying. Normally, it takes 4-5 days for the material to be dried. However, all the above conditions do not prevail in Sri Lanka. If the fruit is suspended, a little above the ground, the drying rate is faster. In addition to direct radiation, convectional air currents occur simultaneously, These account for about 15% of the drying.

In Australia, sun-drying of grapes on racks has been used for quite some time. Large scale drying racks are widely used in the grape growing areas. The drying rack consists of 8 to 12 galvanised wire netting tiers spaced vertically. At intervals along the racks, pairs of intermediate upright posts carry cross pieces that support the tiers. The strucuture may or may not have a roof. A roof is often very practical as it protects the raisins against rain or excessive sun, thus leading to a better quality product. The grapes are sprayed with a suspension of ethyl esters with a small amount of potassium carbonate. Grapes have a heavy waxy layer which is a barrier for drying. By spraying, this is converted from a hydrophobic to a hydrophilic layer thus enabling water molecules to escape. Drying on racks is suitable under climatic conditions of gentle winds and hot dry weather. To permit free air-flow between the racks, they should be located on a rise of land, free of any obstructions. The lower racks are often given a greater tier spacing to compensate for slower air movement near the ground and the upper racks spacing can be reduced.

750,000 tons of grapes are dried every year in the Central Valley, California. Only solar energy is used as there is seldom a weather change. No drying acid is used. Every 10 days the grapes are turned over. Although solar drying has been utilised for generations in America, temperature measurements have been taken only within the last few years. Drying apricots by halving is an expensive method, due to labour costs. A cheaper method is to pulp the apricots and add sulphite, to preserve the colour. This is kept in the sun to dry. The sulphite, also helps to keep insects away. The method is not new and is used principally in Syria.

In Sri Lanka, direct solar energy is used for drying coconut. Solar energy could be used for drying fish in the northern area. It may be possible to speed up drying in wetter areas with simple equipment.

Bangladesh specifically asked the CSIRO for an expert on the drying of fish for which Peter Dowe was sent. The fish is gutted and split and hung on bamboos close to the seashore. These fish dried in this manner are found to have a high microbial and insect content. He set up an arrangement with black polythene behind and clear polythene at an angle in front. By these means he produced a small solar dehydrator. The air is warmer because of the black polythene. Because of the gaps between the 2 layers of polythene there is a convectional flow of air.

By using reflectors made of a cheap material like bituminous paper backed with aluminium foil the drying rate is increased by about 15%. The results were not as good as expected.

Experiments were performed to find out whether it would dry more readily on a black or white surface. A black polythene underlayer was used but no significant difference was obtained.

The relationship between temperature, relative humidity and microbial content of the product were studied. Bacteria do not multiply over a relative humidity of 90% and only some fungi can thrive at a humidity below 62%. Therefore the material being treated must be dried from an atmosphere of relative humidity 80-59% in a very short time. A temperature of 45°C and relative humidity 34% would be very suitable for drying in your country.

The see-saw dryer is simple to operate and is suitable for small-scale drying operations in tropical countries. It is used in Nigeria and other West African countries. It was originally developed for the drying of coffee and cocoa beans. (Fig. 1)

The fruit is spread on a blackened sheet of metal. The sheet balances on a fulcrum, the central axis of rotation running north-south. This makes use of the maximum amount of solar energy available as the see-saw operation permits the drying material to face the sun more directly at all times of the day. This results in a more evenly dried product. There is an optimum angle at which the sheet should be maintained at different times of the day, according to the latitude you happen to be. In your latitude it would have to be almost parallel.

I shall now describe a few types of solar dehydrators.

1. Chamber dryer : This type of dryer is essentially a solar drying box suspended above the ground. It is used for drying vegetables and fruit. Solar radiation is transmitted through the roof and absorbed on the blackened interior surfaces. Holes are drilled through the base of the box to permit air entry into the chamber. Outlet holes are located on the upper parts of the side and near the panels of the box. The temperature inside the box can reach 100°C. As the temperature increases, warm air passes out of these upper holes by natural convection, thus drawing fresh air up through the base. Thus there is a constant perceptible flow of air over the drying matter which removes the moisture. (Fig. 2)

2. A second type of solar dehydrator utilises a solar absorber. The drying chamber and the absorber are built in a one-piece enclosure covered with glass panels. The solar absorber is made of two absorber plates, one being a copper plate treated with a selective surface to increase its absorptive capacity and the other a blackened corrugated iron plate. (Matt black paint will absorb 90% of the solar energy falling on it). A ventilator (usually an electric fan) is designed to pull up a convenctional current of air to ensure quick drying. The product to be dried is put into latticed wire baskets and hung on the walls of the drying box (Fig. 3)

3. A third type of dehydrator is used in Syria. It is essentially a drying chamber through which warm air, heated in a solar absorber is drawn by means of a rotary wind ventilator. The warm air outlet of the absorber is connected to the base of the drying chamber which holds trays placed in two adjacent tiered stacks. Hot air circulates through the drying matter. Additional heating is obtained from solar radiation transmitted through transparent sheets which cover the sides of the drying chamber. The bottom horizontol panels of the dryer are of blackened hardboard to reduce heat loss. (Fig. 4)

In all these types, (a) heat (b) air flow have to be considered. In conclusion I have to say that although solar energy has been used for generations, only during the last 10 years has it been measured. I can see several uses of solar energy in Sri Lanka for drying coffee, copra, cocoa as in other countries with tropical conditions such as Brazil, Barbados etc.

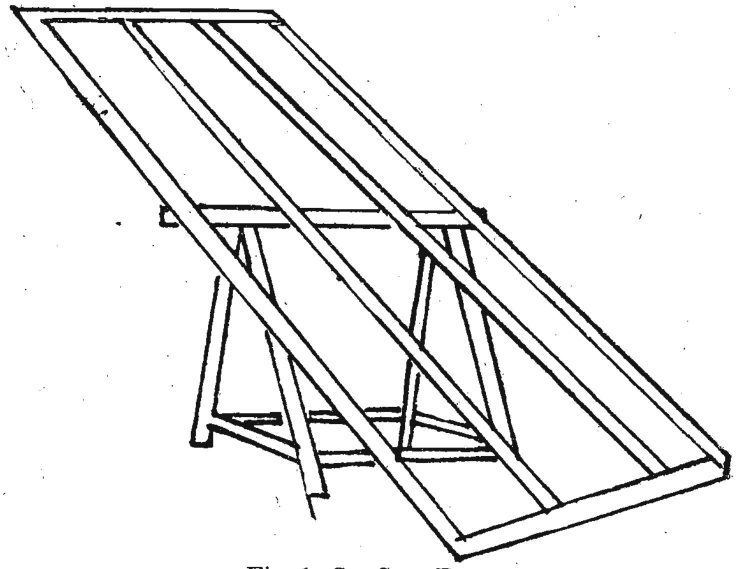

Fig. 1. See-Saw Dryer

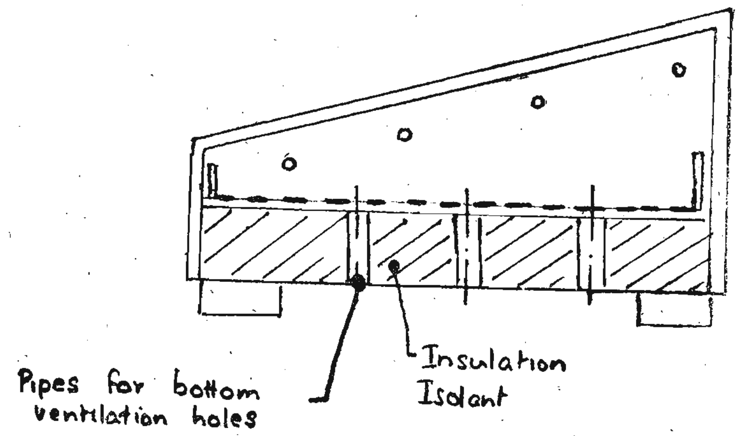

Fig. 2. Chamber Dryer

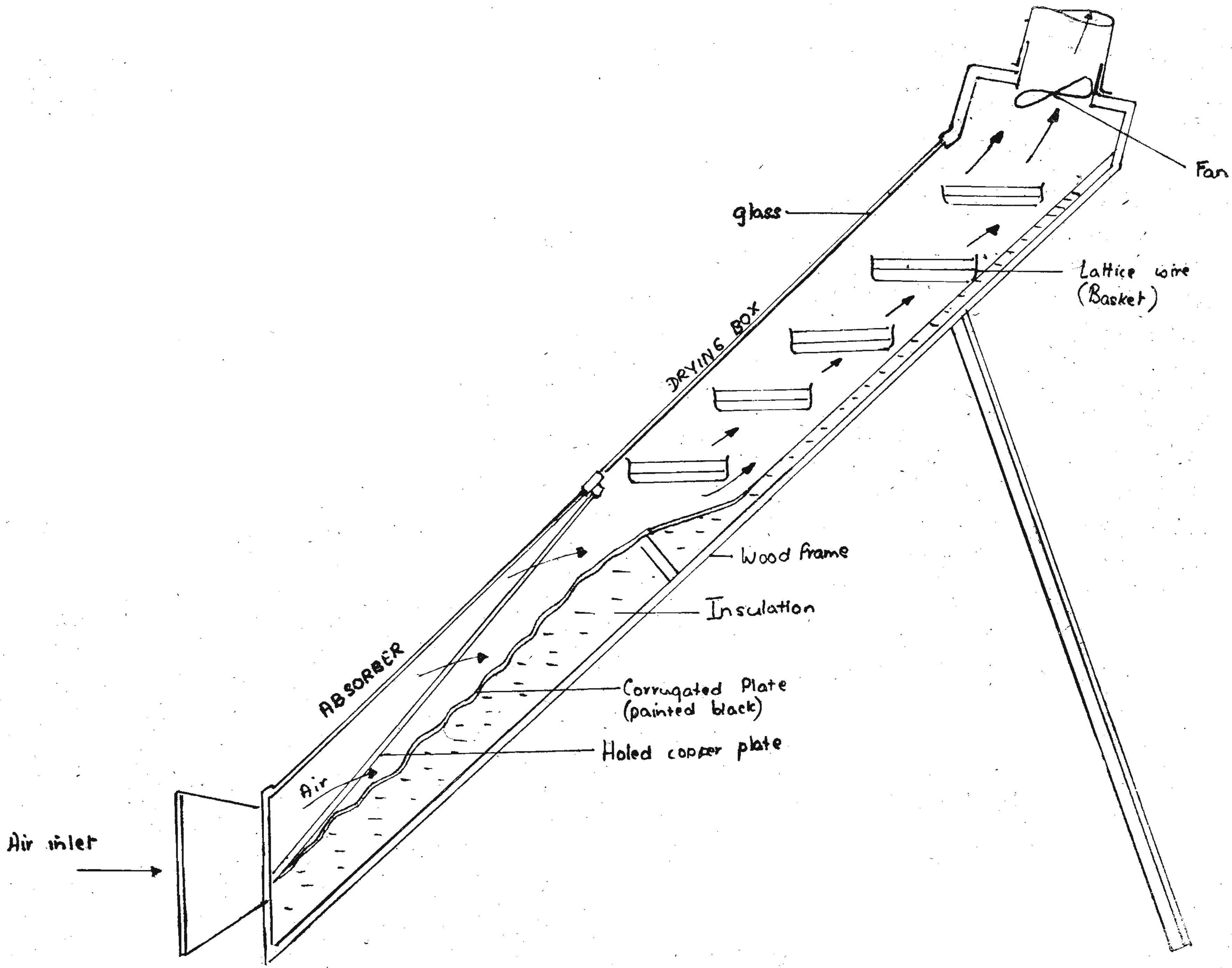

Fig. 3. Solar Dryer

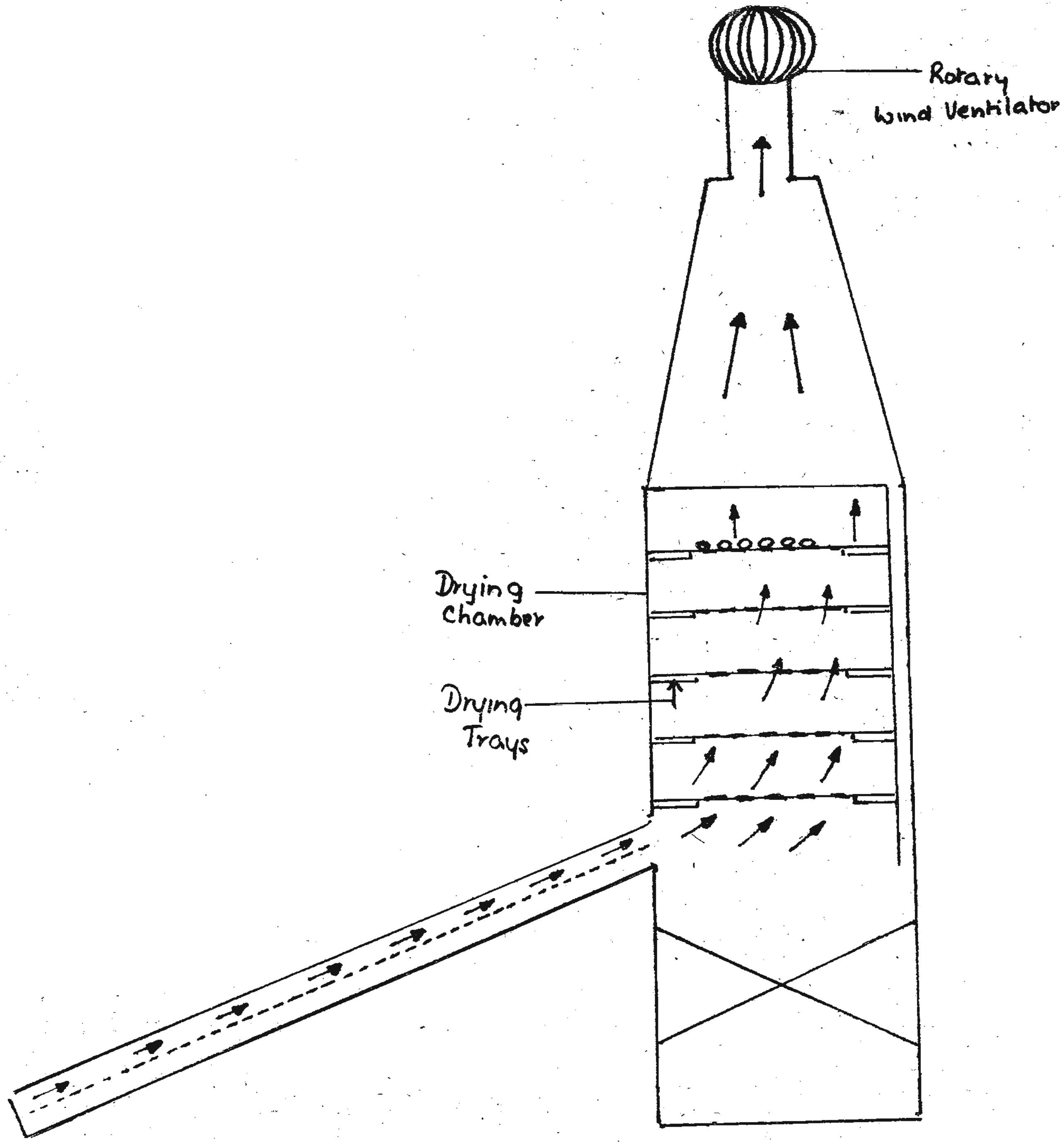

Fig. 4 Solar Dryer

DISCUSSION I

Weerakoon - - Why is metal roofing for drying chambers preferable to glass or polythene ?

McBean - The shelf life of polythene is 2 years but in Sri Lanka it is one year. The cost of replacing polythene is high. Glass is more expensive but longer lasting.

Wickremanayake- In connection with this type of work I used a galvanised iron roof with a false ceiling of masonite. In the first year we saved about 43% of the fuel costs.

Weerakoon - What are the problems you have with contamination by animals ?

McBean - We have to ensure protection from a whole range of animals and insects. But we cannot prevent flies.

Alles - What is your export market for dried fruit ?

McBean - We produce 100,000 tons of sultanas from dried grapes. 60,000 tons are for the export market and 40,000 tons for the home market.
With most of our other dried products about 50% is for export. The bulk of the dried fruit sold in the home market is for cooking purposes.

Alles - What are dried apricots used for ?

McBean - As a sweetmeat in pies and as a snack.
We even thought of drying apricots in square pieces as a sweet.

Weerakoon - I am particularly interested in the fact that in California, the home of technology fruit is dried on the ground.

McBean - Sophistication isn't everything. The cost benefit relationship should be analysed before trying out more elaborate methods.

Vitharana - Do you think drying coconut parings on slats would increase the efficiency of drying ? The slats could be raised about a foot from the ground.

McBean - Raising them about a foot from the ground would increase the drying rate. On the other hand, coconut is loaded with so much oil that the removal of water is inhibited. I think one would have to try it on a small scale.

Bertie Silva - The copra must be broken into half cups, dried in the sun for one day and then in the kilns 8 firings must be done and the coconut shells can be used as fuel. You should have experience in drying materials sensitive to sunlight. If peaches or pears are dried in direct sunlight for too long a period they get bleached. That is why they are dried for a certain time in the sun and then by convection currents. You have to watch the material. For papaw and mango, the color ing might deteriorate. In the early stages, the evaporation rate is such that the temperature of the material is usually well below that of the surroundings. You have to study your environment with existing knowledge.

Abeywardene - We tried to dry cardomons but we could not effect drying by utilising air movements from convection currents.

Wijesekera - Cardomons have a skin, which is originally green, having 6%-8% volatile oils. This waxy layer is a distinct barrier for the removal of water.

Our problems were:-

(1) bleaching of the skin

(2) an aziotropic effect of oil and sun occurs, when exposed to too much sunlight. Sodium carbonate is added to retain the colour.

McBean - It probably has a pH effect. The pH of sodium carbonate is about 9, therefore keeping the chlorophyll green. It may also be removing some steroids.

Wijesekera - We used intermittent sun-drying and later drying in a house. Another factor caused by too fast drying is contamination. We designed a dryer like the LeMarc one you made.

McBean - You may need a helping hand.

Wijesekera - If you draw a prototype, we can discuss it.

Abeywardena - The basic problem with the LeMarc dryer is that the rate of drying is even slower than outside.

McBean - The same problem occurs in the drying of fish.

Wijesekera - This is due to heavy condensation.

McBean - Obviously there are no air currents. Two of the side walls of the dryer could be transparent. Energy from direct radiation could be used. When drying cabbage or any green vegetable one of the essential points is to dip it in an alkaline solution. Due to the pH the chlorophyll is not destroyed.

Weereratne - Have you also measured at what level the microbial action is at a minimum ?

McBean - We do what we call a microbial count. No microbial population will grow below a moisture content of 20%. If the moisture content is raised to 30% some moulds will grow.

Weeraratne - Have you got the figures worked out for each type of material ?

McBean - Yes, but I realize it is one of the major problems.

- Artificial drying is very expensive. Does the CISIR do any project on this ?

Abeyratne - No.

McBean - So many different bodies are trying out different commodities which is wasteful.

Weerakoon - We should channelise our efforts in this direction.

Overview of Problems of Sun-drying in Sri Lanka

L.A.C. Alles

I am trying to overview the entire region of sun-drying but do not know how competent I am as this has not been an area in which I have worked, except as a student from a fundamental point of view. I am doubly happy to participate in this seminar as I started my food science work as an Australian Fullbright scholar under Mr. McBean.

I would like to extend this review not merely to drying but to solar energy drying. Solar energy drying is limited but drying itself covers a more extensive area. We are trying to seak areas where research is possible. This is intermediate technology, right down to earth. The final evaluation must be on an economic and practical basis.

Drying itself has two aspects :-

(a) material for drying

(b) methods or means of drying.

I hope we could, at the end of this seminar, isolate a few research and development projects which we in Ceylon, either on our own or with foreign expertise, could put into operation. This is one of the main objectives of the seminar. We may be able to persuade ASCA and our own scientists to cooperate on this issue.

All these materials being biological are subject to deterioration- microbial, chemical and physical. Our exercise in drying is to limit these reactions.

We have to consider storage over long periods of time.

Cereals : Paddy is the raw material we are most concerned with. Mr. McBean said that his familiarity with rice storage is limited. This is certainly the most important area for us and one which we could investigate further. 2 million metric tons of rice have to be stored per year in Sri Lanka. The deterioration of stored rice could be due to two causes - microbial action and humidity. After par-boiling, the method used is primitive. I do not mean this disparagingly, but that the simple method of drying by spreading the rice on the floor is used. The methods applied vary from region to region, in the dry and wet zones. Wind velocity is higher in the dry zone.

Since Dr. Wickremanayake is here I will leave that point to be amplified by him.

Drying problems arise with Kurakkan, maize, sorghum and meneri. 4000 tons of these cereals are produced per year.

Fish : 45,000 tons of dried and salted fish are required per year in Sri Lanka of which 10,000 tons are produced locally. From the discussions with Fisheries Personnel, Mr. McBean has got some idea of the problems associated with drying fish. In the drying of fish, several factors have to be considered. It is not only solar energy that is important but wind velocity and effective air-flow rate. For this, the trays on which the fish are dried must be raised above the level of the ground. I do not think sufficient work has been done in this field. I leave the area of fish drying to be magnified by others in the seminar.

Fruits, Vegetables : The next category I went to deal with are fruits, spices, vegetables and tubers. Legumes like green gram and cowpea can supplement the protein diet. Because of the lack of sufficient nitrogen fertilizer proper storage of these materials is essential. Drying of produce like chillies have been studied very intensively by the neighbouring countries such as India, and we can apply these methods. The CISIR has been working on this.

Drying of spices in Kandy, Matale and other areas is very primitive by the roadside. Attendant losses occur in the yield of essential oils by these methods. Research projects could be formulated in this field. Jak and breadfruit are dried in homes and not on an industrial scale. I believe one could upgrade drying of these fruits by introducing techniques such as blanching or sulphuring and giving incentives to fruit growers. By these methods these seasonal fruits can be exported. The only other variety of fruit dried even to a small extent is lime for pickles. A fair amount of discussion has taken place concerning the drying processes involved in the manufacture of tea, rubber and coconut. In the process of manufacturing coconut products it is a question of the utilization of energy which is now wasted. At present the heat obtained by burning the coconut shell is used. It is a drying process where the economy has never been considered.

In the case of tea manufacture the temperatures used are so high that the use of solar energy is ruled out. The metereological records give us the following data : Relative humidity -70%-80%(day)

Sunshine hours per day 4 - 6 .

Wind velocity in the coastal areas is high and therefore useful for drying.

Problems of Drying Paddy

V.E.A. Wickremanayake

The Paddy Marketing Board handles the post-production operations in paddy i.e. from harvesting and threshing through storage and processing to marketing.. All of our paddy is sun-dried, mostly in the field before harvesting. Field yields are highest when paddy is not allowed to dry beyond 18-20% moisture content at harvest time. (Farmers usually harvest at 13% to 14% m.c.) Yield increases of up to 1800 lb. per acre could be realized by harvesting at optimum moisture content. This necessitates two essentials:-

(i) a mechanical thresher to thresh high moisture paddy, since conventional methods cannot be applied efficiently

(ii) some technique of drying to enable paddy to be stored at 14% m.c. or less and avoid losses in storage.

Currently the Paddy Marketing Board estimates losses of 2 or 3 million rupees for an year as a result of storing high moisture paddy. These losses are due to respiration and consequent breakdown of starch, attack by insects and fungi and loss of rice quality.

Another drying problem faced by the Paddy Marketing Board is connected with the drying of parboiled paddy before processing. Parboiled paddy has to be dried from 35% m.c. to 14% m.c. before it can be milled. The usual process employed is sun-drying on paved drying floors with women workers turning the grain with their feet. Rice quality is largely assessed on the broken grain content after milling. Uncontrolled drying causes cracking of grain and consequent increase of brokens in rice. Drying has therefore to be carefully controlled and done in stages with 'tempering' periods in between.

Solar drying, particularly in the drying of parboiled paddy is dependant on weather conditions, and has therefore to be supplemented by artificial drying facilities during rainy weather.

Problems of Drying Tea

Dr. R.L. Wickremasinghe

The types of tea manufactured throughout the world are

1) Black tea
2) Green tea
3) Oolong tea (Taiwan)
4) Paochong tea (Taiwan)
5) Brick tea (Russia)
6) Pickled tea (Burma)

Sun drying has at the present time only a very limited application in tea processing, and is confined to its use in producing so called "tippy" teas, which are occasionally produced for markets in countries in the Middle East. In this instance carefully selected buds of tea shoots may be sun dried to effect destruction of the chlorophyll present in the bud and the resultant formation of "silver tips". Such "tips" are popular in Middle Eastern countries, where they fetch premium prices.

Black tea which is the most widely consumed form of tea, involves 3 main processes in its manufacture, viz. withering, fermenting and firing, and there is a progressive loss of moisture at each of these stages. Plucked tea shoots contain about 80% moisture, which is reduced to about 60% during the "withering" stage, where the leaf is spread on "troughs" or "tats" and allowed to senesce for 16 - 18 hours. Thereafter the withered leaf is macerated and allowed to "ferment" for 1½ - 3 hours, when the moisture level drops to around 50%. In the final stages of "firing" the fermented leaf is dried in a current of hot air (170°F) for 21 minutes, when the moisture level drops to 3%. The conventional tea drier used for this purpose for the last century or so may, in the future, be replaced by the newly developed fluid bed drier. Apart from reducing the moisture content to a level at which the tea may be stored without undergoing deterioration, "firing" also causes destruction of enzymes (eg. polyphenol oxidase) and the conversion of chlorophyll to phaeophytin, which is responsible for the blackness of tea.

It has been found that chlorophyll can undergo two types of transformation during tea processing.

Chlorophyll → chlorophyllide → phaeophobide

Chlorophyll → phaeophytin

The enzyme mediated change results in a tea which has an undesirable brownish appearance, whereas the direct conversion to phaeophytin is important for the black appearance. Another effect of firing is loss of about 40% of the volatile compounds present in fermented tea leaf. Volatile compounds are responsible for the all important flavour of tea, and their loss during firing may, at first sight, appear to be an undesirable feature. It has, however, been determined that the volatile fraction of tea contains more than 150 different compounds of varying boiling points, and that a high relative proportion of low boiling compounds (eg. di-methyl sulphide, trans - 2 - hexenal) to high boiling compounds (eg. linalool, B - ionone, cis - jasmone) is detrimental to tea flavour. It is possible, therefore, that the relatively greater loss of low boiling compounds during firing would actually improve tea flavour and so greatly enhance the value of the finished product. Unfired fermented tea also has a very astringent taste, which is "rounded off" and mellowed on firing. The reason for this beneficial effect is chemical combination of the polyphenolic material with the proteins present, which results in a partial neutralisation of the astringency of the former. Another chemical reaction which occurs during firing of tea is combination of keto compounds with amino acids, resulting in the formation of coloured compounds which enhance and improve the colour of tea liquors. It is evident, therefore, that several changes, which are of crucial importance to the commercial value of a tea, occur during the drying of fermented tea leaves. Any attempt to substitute sun drying for the methods used at present must take cognizance of the necessity to ensure that the traditional requirements of a processed tea must be maintained.

Problems of Drying Coconut

Mrs. K. Vitarana

Solar energy has been used from early times for the drying of coconut. One of the earliest of dried coconut products is copra which is made by drying the coconut kernel complete with testa to about 7% moisture. Sun-drying is used in the manufacture of copra and sun-dried copra is generally superior to kiln dried copra i.e. if the conditions are good, like strong sunshine and no rain, etc. If not, the problem of sun dried copra is that it can get a high mould count. Copra is also dried in kilns by firing coconut shells for ordinary commercial purposes depending on the quality of the nut. However for the extraction of oil for commercial purposes, a high quality copra is not required and therefore we have not paid much attention to improving the quality of copra from kilns. It may be possible to use solar energy for the manufacture of kiln copra too.

The main problem encountered in the drying of coconut is in the preparation of desiccated coconut. This required a high degree of skill. The kernel is first pared and then disintegrated in disintegrating mills, and then dried in ovens or desiccators. The cut coconut has to be dried down to a moisture content of 3% or lower. The oil content which is approximately 37% before drying, rises to 68 - 70% later in the dried product. There is a wide variation in the size of particles which varies from 4 mm., to less than 1 mm. in diameter. Desiccated coconut is somewhat similar to tea in this respect. In fact, the tea dryer has been adapted for the desiccated coconut industry and most of the drying equipment available in desiccated coconut mills is old tea industry equipment. In the old fashioned tea dryer, there is a furnace that may be fired by wood and more recently by liquid fuel. This furnace is a heat exchanger type. Air from outside circulates among the heated tubes of the furnace and then enters the desiccator. In this furnace the flue gases are not in contact with the hot air that dries the coconut.

The flavour and appearance of desiccated coconut is important. The white colour has to be preserved. We have to be careful to prevent leaks in the furnace, otherwise the desiccated coconut will get a smoky flavour and also become grey in colour. The smoky flavour can come from smoke from the charcoal burning pits coming into the desiccators through the chimneys. The choice of wood for the furnace is important. For example, you cannot use rubber wood because this will affect the flavour.

It is also important that the desiccated coconut should not be oily. When oily, the desiccated coconut lumps together and is difficult to handle. Oiliness can occur due to cells getting damaged during disintegration.

Desiccated coconut should not be contaminated with sulphur dioxide. When direct firing with fuel oil is used, some of the by-products such as polycyclic hydro-carbons could contaminate the desiccated coconut. Sulphur dioxide is an indication of this contamination. Some polycyclic hydro-carbons are carcinogenic.

In the old type desiccator, the drying chamber consists of 5 - 8 trays made of wire mesh, moving in intervals of 5 - 10 mins. each. Each tray can carry about 30 lbs. of coconut spread in layers of 1½" thick. Hot air is drawn into the desiccators by an induction fan. The temperature should be regulated at this stage and should be between 190 - 200^{o}F. The hottest air first comes in contact with the tray bearing the driest coconut. The circulation of air therefore follows the counter current principle.

There are other driers for coconut. The Colombo Commercial Company devised a drier which was an adaptation of a tea drier and is known as a semi-automatic drier. In collaboration with the Tea Research Institute and the Colombo Commercial Company we are also experimenting with a Fluid Bed Drier which is now being used for tea. In the Philippines, the steam heated drier known as a Proctor Schwartz is used. Heating is by steam coils and the drying chamber has moving trays. Humidity is carefully controlled. This is an expensive method and we have therefore not considered using it for our industry. A lot of heat energy is wasted by being sent out to the atmosphere.

Problems of Drying Rubber

Dr. R. Tharmalingam

In raw rubber manufacture, drying is the final process prior to to packing. In Sri Lanka three types of rubbers are manufactured for export. They are:

1) Ribbed Smoked Sheet (RSS)
2) Crepe Rubber
3) Block Rubber

Drying characteristics of Rubber

In the case of smoked sheets, the coagulum is milled in the form of sheets and dried in smoke houses. Firewood is used as the fuel for the smoke houses. The initial moisture content is about 40% on dry rubber. During the initial stages of drying, i.e. the constant rate period, the sheet remains at the Wet Bulb Temperature of the drying air and the loss of water is by both evaporation and synerisis. At the end of this stage of drying, the moisture content reduces to about 15%. During the final stage of drying, i.e. the falling rate period, which occupies 85% - 95% of the total drying time, the drying rate is controlled by diffusion within the sheet. The average drying time for rubber in the form of sheet is about 4-5 days and the temperature of drying is about 60°C.

For the manufacture of crepe rubber, the coagulum is milled into thin laces and dried in multi-storeyed buildings. The drying tower is artificially heated using hot air at about 34°C. Boiler-radiator system is the most commonly used heating equipment for crepe rubber drying. The average initial moisture content of these laces is about 10%. During the constant rate period the moisture content reduces to about 3%. The falling rate period occupies about 80% of the total drying time and the final moisture content is less than 0.2%.

In the case of block rubbers, the coagulum is comminuted prior to drying. The comminution process is carried out using granulators or creper/hammermills. The granules are dried at 100-120°C for about 3-4 hours in deep-bed driers. The initial moisture content of the granules is about 40%. The moisture content reduces to about 10% during the constant rate period. 90% of the drying time falls within the falling rate period. The final moisture content is less than 0.5%.

Possibilities of utilising solar energy

Experiments carried out at the RRISL show, rubber in the form of sheets can be sun dried during the initial stages of drying (about 3 days), and further drying can be carried out in smoke-houses.

In the crepe rubber manufacture Rubber Peptizing Agents (RPA) is added to bleach the carotinoid pigments present in the rubber. Direct exposure of the laces containing the RPA to the sunlight will affect the quality of rubber. Therefore, it is not possible to sun-dry rubber in the form of laces for crepe rubber manufacture. But there is a proposal to carry out experiments on a pilot plant scale in collaboration with the CISIR to find out the possibilities of using solar collectors to provide hot air to the crepe drying towers. In Sri Lanka the daily average of solar radiation received amounts to about 4KW hr/m^2 (1300 Btu/ft^2). The energy requirement of a 9000 lb. capacity drying tower for crepe has been estimated to be about 50000 Btu/hr. On this basis with a solar energy conversion efficiency of 60%, a solar collector surface area of 800 ft^2 would be adequate for the drying operation during the day light hours. This area is almost equal to the area of roof of the drying tower. Anyhow, during rainy days and during the nights, artificial heating will be required to supplement this solar energy system.

In block rubber manufacture, the temperature of drying is high compared to that in sheet and crepe manufacture. The block rubber factories normally handle a very large crop and it will not be economical to use solar collectors to provide hot air for block rubber drying.

Therefore, in the field of rubber, it is only possible to utilize solar energy to dry rubber in the form of sheet and crepe.

DISCUSSION II

Alles - What is the moisture content of paddy when purchased?

Wickremanayake- Ideally it should be 14% moisture. However we are forced to buy at 16%-20% moisture content as farmers do not have drying facilities.

Bertie Silva - Do you dry paddy before storing ?

Wickremanayake- Not at present. We will be using a mechanized dryer.

Wickremasinghe- Is it practical ?

Wickremanayke - It is practical but not economical.

Bertie Silva - Do you always sell rice as par-boiled ?

Wickremanayake- Only 60%. The bulk of our purchases is in the Maha and Yala periods. Our policy is to process the rice and sell it regularly throughout the year. Hence our problem is storage.

Weerakoon - You said that you lose about 1600 lbs. per year when farmers sell it with a high moisture content.

Wickremanayake- The same problem occured in India. A drying machine and thresher were used.

Weerakoon - Government should be persuaded to adopt these measures.

Bertie Silva - In Sri Lanka we use sun-drying and a hand thresher.

Wickremanayake- But if a man has 2 or 3 acres, it is a real problem. A small 2 wheeled-tractor can be used to work a thresher.

Weerakoon - I should like to ask Dr. Tharmalingam for his opinion on this.

Tharmalingam - We have/a pilot plant at Agalawatte and will be investigating the amount of sunshine required.

Bertie Silva - For this purpose you must have thermostatic control.

Some Experiments in Drying Fish

K. Satchithananthan

Dried fish is one of the cheapest and most convenient forms of concentrated fish protein available in Sri Lanka. The traditional and most popular method of fish preservation is by sun-drying. However the quality of sun-dried fish is poor as it contains sand and a high moisture content. So far there has been no quality control over production. No investigation in this field has been attempted except by Peterson and Weerakoon (1951). They compared the efficiency of airdrying and sun-drying and reported that the rate of drying of the fish samples exposed to the sun was greater than in the case of those drying in the air, and the final dry matter content higher. They have suggested that further experiments be conducted with the view of obtaining more definite information on artificial air drying.

The experiments conducted at the Fisheries Research Station by Miss Kumaraswami and myself are of an exploratory nature with a view of finding out the nature of sun-drying and using this information for our experiments in artificial drying.

Mr. C. Alagaratnam and Mr. K. Vivekanandan of Walker Sons Ltd., Colombo have designed an artificial dryer using the heat exchange principle. This dryer was used in our experiments to work out an economically feasible drying process to achieve a product that would be superior to the quality of the sun-dried product.

Sun-Drying : We have experimented on Mackerel (Rastrelliger Kanagurta) and Leatherskin (Chorinemus lysan). Sun-drying of fish takes 6 hours per day for 4 to 5 days. The moisture content comes down from 70% to 31%. Two methods of salting were employed:-

1) Wet Salting
2) Dry Salting

Wet Salting : Musculature scarified and fish soaked in a saturated solution of salt with excess salt for 18-20 hours. Samples were spread open on a wire mesh tray and kept in direct sunlight and kept over-night in the laboratory (in shade) for 18 hours, then sun dried again for 6 hours for removal to shade after that. This process was repeated for 4 days until the fish became hard and well dried.

Dry Salting : Musculature scarified and coarsely ground salt applied onto its surface and into the incisions in excess and kept for 18-20 hours. Samples were spread open on a wire mesh tray and kept in direct sunlight for 6 hours. Drying procedure was the same as for wet salted fish. Analysis for moisture content, protein content and total bacterial count were made at the end of every 6 hours of sun exposed each day.

The rate of moisture removal during sun-drying is faster in the dry salted fish than in the wet salted fish in both species. The bacterial count is generally higher in wet salted fish than in the dry salted fish.

Artificial Drying : Walker Sons Ltd., Colombo, a commercial enterprise, has constructed a pilot plant for drying purposes. This plant uses electric power for starting operations and a diesel burner to heat the air. The hot air is let into a chamber, where wire mesh trays are arranged one above the other. The hot air is recirculated if necessary. The heating equipment is a heat exchanger and the gases of combustion are let out through a chimney. The temperature of the chamber, the rate of air flow, and the amount of recirculation are adjustable to required levels. Fish samples were dried in this chamber. The samples were drysalted as described earlier, and spread evenly on the wire mesh trays. Mackerel, (Rastrelliger kanagurta), Leather skin (Chorinemus lysan) and Horse Mackerel (Caranx sp.) were the types of fish used in the experiment.

Mackerel dried at 50°C - 70°C for 5 hours was partially baked, and had a semi-cooked soft texture. Horse Mackerel and Leatherskin dried at 36°C - 42°C for 9 - 12 hours had the desired effect of a hard well dried product.

Consumer Preference and Standards for Dry Fish and Other Dried Foods

Dr. Nihal de Silva

The study of the drying of fish dated back to 1949. In 1956 papers on dry fish manufacture were read at the CAAS sessions. In studying any process in the manufacture of food the consumer demand has to be taken into consideration.

The sources of energy on the earth's surface are

		cals/cm^2/yr
(1) Total radiation from the sun		260×10^3
(2) Ultraviolet radiation	2500°A	570
	2000°A	85
	1500°A	3.5
(3) Electrical discharges		4.0
(4) Radioactivity		

The flavour of dry fish does not improve with keeping. If that is so we should prefer imported dry fish which is of a poorer quality than the local product. However we do not maintain standards as there is no quality control. Good quality dry fish should have the following properties :-

(1) should be compact for storage and transport
(2) should have rapid and ready retention qualities
(3) able to withstand tropical conditions
(4) be nutritious

A Quality Control Centre was established at the CWE. The standards we arrived at for the quality control of dry fish have been accepted as the national standards of India and Pakistan.

The quick drying inhibits theoutflow of moisture from the interior of the fish*. In Ceylon the temperature conditions and wind velocity are within the range of the optimum but relative humidity is too high.

* If drying is too slow, pebbly crystals of salt form on the fish and this is not very acceptable to the consumer.

Ideal drying conditions

Air velocity	200 - 300 ft/min.
Air temperature	16 - 27°C opt. 24°C
Relative humidity	45%- 55%

There is also a dryer designed by FAO experts in Ghana. This is built on a traditional pattern of trays, pivoting on a central bar. A fan is used to circulate air.

The effect of direct sunlight on the drying of fish is not very good. The ultraviolet rays cause certain oxidative processes for example fatty acid oxidation which is harmful for human consumption. We tried methods of drying the fish in a collapsible double roofed shed either keeping fish flat or vertical. This was a primitive form of solar dryer.

In Ghana, indirect heat transfer is used which has the advantage that even in the absence of sunlight, drying can be effected.

The main factor which causes the deterioration of dry fish is excess moisture. Of samples examined, 62% had excess moisture and had to be rejected. Cittic acid has a preservative effect, because of its pH effect which changes the permeability of the cell membrane and not because of its action on bacteria.

Chillies : There is a loss in pungency of chillies when heat dried. The reasons for rejection of dried chillies are (1) decolourisation (2) moulds and (3) insects. The CWE fixed standards of moisture content at 14%. If we can reduce the moisture content to 12.5%, the percentage contamination reduces from 35%-20%.

We have already done some work on other effects of sunlight, for example on Sitophillus that attacks rice. Under dry heat, 90% to 100% are killed but under moist heat, the death rate is very much lower.

In India infra red light has been used to sterilise grain. This work in this field is still continuing.

DISCUSSION III

Wickremanayake - I like to ask Dr. Satchithanandan about the dryer he mentioned. Is it designed to recycle air ?

Satchithanandan- There is 100% recirculation. The relative humidity and temperature of the air issuing from the outlet is measured.

Bertie Silva - In the Phillipines, a monitoring system is used to measure the moisture content. Temperature is maintained at 230°C - 240°C and the air is recirculated until it is almost 100% humid, when automatic valves operate.

Weerakoon - What is the extra cost of artificial drying ?

Satchithanandan- 50 Cts. extra per lb.

Bertie Silva - In what part of the island is the artificial dryer used ?

Satchithanandan- We tried a beche-de-mer dryer designed by Walkers in Manner. It holds about 4000 tons.

Bertie Silva - An extra cost of 50 cts. a lb. on 4000 tons comes to a sizable amount. We are trying to reduce the cost to 10 to 12 cts/lb.

Alles - Small scale experimentation should precede commercial use. We have outlined a set of investigations to be conducted on a small scale, to be elucidated from the point of view of chemistry, microbiology, etc. Small scale investigations have to be carried out to identify the parameters.

Satchithanandan- We have not intention of extending this pilot plant to commercial practise.

Wijesekera - What is the role of salt in the drying of fish ?

Nihal Silva - There are three reasons for adding salt:

(1) osmotic dehydration
(2) control of microbial content
(3) taste

The addition of salt causes changes in the protein of fish.

McBean - A large number of Biochemical changes/in the canning and freeze drying of food stuffs. I think we should study the changes in the material during the processes rather than the methods.

occur

Weerakoon - Did Dr. Silva say that people look for similarity between fresh fish and dry fish.

Nihal Silva - In 1952, a survey was done by the FAO which clearly showed that a large percentage of consumers of dry fish belonged to the lower income groups who certainly preferred a resemblance to fresh fish. We must try to produce a product which provides protein in a soft form.

Weerakoon - Does a consumer who buys dry fish want it to taste like fresh fish ?

Nihal Silva - I don't know. I can only go on the survey.

McBean - Nobody eats fresh prunes in Australia. Everybody eats dried prunes.

Weeraratne - If the process of drying is to be successful, bacterial multiplication has to be controlled.

Satchithanandan-What happens is that the initial bacterial load is heavy and then it comes down.

Nihal Silva - One must sound a word of warning in the use of the word bacterial count., as it depends on temperature, etc. Doing a straight forward count on the product at every stage of processing does not mean much.

Weeraratne - You said that moist heat kills faster than dry heat. Moist heat destroys the protoplasm faster.

Nihal Silva - Jayantha Fernando is studying the field infestation of paddy. Bisser is found in Africa. Lipea is very photophobic. Sitophillus is much more resistant. In the case of Lipea as soon as you expose to the sunlight they go away.

Wickremasinghe- Most farmers dry their paddy. If the paddy is dried to 12% moisture content it can kept from pests. Our problem is not Lipea but Gulla. Lipea can be controlled by spraying.

Weerakoon - You said that farmers here have got lax.

Wickremasinghe- As people get more sophisticated the traditional methods are discarded.

Nihal Silva - One of the things about sun-drying is that I think we should work on a combination treatment. A combination of sun-drying and the spraying of repellants should be used in the control of pests.

McBean - Anything that can speed up the rate of drying will result in less chance of microbial infestation. Anything with a high acid content is useful as a natural preservative.

Alles - Nolli has a high citric acid content.

McBean - Sulphur dioxide is fairly commonly used in Australia. But it is a bleaching agent. Sulphur dioxide prevents non-enzymic browning and acts as an anti enzyme. Potassium chloride is used for softening fruit, as people are prepared to pay a premium of 50% for the softened product. But this increases the chance of microbial infestation. You can also spray the material with a very weak solution of potassium sorbate. Potassium is metabolised in the body when used in concentrations of about 1%. I don't think we have sufficiently investigated all the combination methods as yet. However, I do not know what methods you have in your country.

Nadarajah - In the sun-drying of rubber, five hours exposure to sunlight is deleterious, because moisture absorbs the ultraviolet light, destroying the natural tocopherols present in rubber.

McBean - What kind of exposure is necessary to remove the natural oxydants ?

Nadarajah - Indirect heating is necessary. Therefore a wet sheet is kept next to a dry sheet.

Alles - I think we have covered a wide area today. We should now isolate several topics in order of priority.

Weerakoon - I was asked whether the Seminar on Sun-Drying proposed to go back to the use of primitive methods, but I said that we hope to improve on existing ones. This is an important seminar as it might point to cheaper methods without imitating sophisticated ones. However if the simple method is not effective, I am not advocating it.

Mr. McBean could you please give us some impressions on sun-drying in Sri Lanka.

Impressions of Sun-drying in Sri Lanka

D. McBean

The preservation of food has been a major problem all over the world. When I was in California in 1968, I saw a very sophisticated freeze dryer which was much admired by everybody there. But this is the type of technology which we do not want in this particular seminar. This does not mean that I advocate primitive methods, but it is because these methods adopted by advanced countries would be too expensive. Some advanced countries are finding it difficult to maintain their equipment. I am sure that people here are capable of exploiting the available solar energy to solve their problems.

After listening to all the speakers, I have arrived at the following conclusions :-

(1) Drying of grain is the most pressing problem. Research in this area seems to be going in the right direction. I feel that your solutions lie between simple and very sophisticated technology. More work should be done at ground-level.

(2) The drying of tea is one of the most important problems as tea is an important foreign exchange earner. The present method could be improved if some supplementary energy could be used. At this stage I cannot visualise the utilization of solar energy in the tea industry in the near future.

(3) In the drying of coconut, a considerable amount of solar energy is required. I do not think that a considerable increase in the rate of drying over the present methods used, can be effected.

Copra drying has changed from using a kiln dryer to using a fluid bed dryer. A building should be designed to collect a considerable amount of solar energy, which can be fed as a supplementary energy source to a heat-exchanger.

There does not seem to be sufficient cross fertilization of ideas among scientists in Sri Lanka. When I come up with a problem, I look up some one in another division of the CSIRO. I think you can never get enough of this kind of collaboration.

I also suggest that one of your large coconut processing plants should examine heat wastage.

(4) Rubber : The problems of exposing rubber to direct sunlight were discussed. I suppose that small amounts of heat are required for successful drying.

(5) Fish : I think there are 2 areas to be worked on :-

(a) On the use of equipment
(b) The concentration of gas necessary

We were fortunate to get some Japanese equipment that could measure the concentration of sulphur dioxide on the spot. As far as fish drying factors are concerned, I am not sure whether enough basic knowledge has been accumulated.

Finally I think that you should collect information on

(1) antioxydants which are available to you
(2) examine basic water relations-that is the suitability for the growth of microorganisms.

That, Mr. Chairman is my brief summing up.

DISCUSSION IV AND RECOMMENDATIONS

Weerakoon - Using the guidelines laid down by Mr. McBean and Mr. Alles we should draw up a scheme. The general public has a very hazy idea of work being done in this field but to get the necessary finances the public should be made aware of these problems.

Wickremasinghe- I wonder whether investigations done on tea pests could aid work being done on paddy pests. The moulting hormone of the shot-hole borer, which is a sterol, is affected by spraying saponin. This prevents the metamorphosis into the adult. If we dust paddy with saponin, I wonder whether we could prevent insect attack.

Wickremanayake- Sitophillus, the main insect pest of paddy comes out of the bag in which paddy is stored to mate. We could kill the insect as it comes out without treating the paddy by treating the bag.

Wickremasinghe- At what moisture content is paddy attacked ?

Wickremanayake- Anything above 12½%-13% is attacked.

Alles - If we set out a list of priorities the National Science Council can draw up a set of recommendations. We should now summarize the conclusions and recommendations of the house.

Vitarane - Paddy should be given priority.

Wickremanayake- Although paddy should be given priority we should think of processes where sun-drying is most feasible. What about fish meal ? At present we import dry fish and fish meal.

McBean - I am not sure whether solar energy could be used in the making of fish meal.

Weerakoon - Dr. Silva would you like to comment on this ?

Nihal Silva - I dont think we can utilize solar energy for the preparation of fish meal except by using solar cookers. A simple powder made from skins and bones that can be dried in the sun should be used as fish meal.

Alles - Mr. Wickremanayake objected to paddy being given priority.

Bertie Silva - Paddy being the staple food of this country, we should try to utilize solar energy to dry it. An attractive premium should be given to farmers for well dried paddy so that he gets an incentive to dry it.

Wickremanayake - I think a little explanation is necessary here. It is not a free market in paddy. Very little paddy goes into the open market.

What does the farmer do with wet paddy ? What he does now is he tries to sell it immediately as he has no place to store it. There are about 360 government stores for paddy.

Bertie Silva - At present we use fuel oil to dry paddy.

Wickremanayake - We should try to find methods of using solar energy.

Weerakoon - Paddy should be given priority in our scheme.

Allea - What is Dr. Wickremanayake's objection to this ?

Wickremanayake - I did not object to this proposal but I feel that we should think of the feasibility.

Weerakoon - The National Science Council and University would realize the importance of channelling funds for research along these lines.

Wijesekera - I suggest that you list the items but not in order of priority and then give the recommendation.

Rodrigo - I think we should include dry zone vegetables.

Alles - I agree with you but I find that the market for dry zone vegetables is a local market and the price is low. Value is acquired after drying.

Rodrigo - The sale locally is low. There is a market abroad for soups etc. During the production season there is a glut. This should be utilized to make soup packets etc. to be used in times of scarcity.

Nadarajah - We did some work on rubber in this direction. Rubber seed is a waste material. To preserve it, it has to be sun dried for 3 days. The full potential is 7000 tons of rubber seed oil.

Nihal Silva- We have not dismissed dry zone vegetables in our work on solar drying. A survey done by us about 4 years ago showed the food crisis could be solved to some extent by the proper preservation of dry zone vegetables.

Weerakoon - I supposed you want to know whether present technique can be further investigated, Dr. Silva ?

Nihal Silva- Oh yes, it involved a major problem of spoilage by microbial infestation.

McBean - I suggest that technologists designing solar dryers in Sri Lanka should aim at obtaining the highest possible amount of solar absorption.

Vitarana - I suggest that the National Science Council should do a literature survey.

Weerakoon - Dr. Wijesekera as Acting Secretary-General, what do you feel about this ?

Wijesekera - I would recommend training chemical engineers who will help us to clear these problems.

McBean - The Brace Research Institute of McGill University in Quebec has conducted a great deal of research on the practical usage of solar energy. It would be useful to establish personal contact with scientists in that Institute.

Alles - As a sequel to this seminar, how far will ASCA be committed ?

McBean - ASCA wanted me to assess the problems in the 3 countries I visit and to outline possible lines of action.
They cannot afford much financial assistance.
They preferred to work along lines that would help several countries. May be you could send some proposals to ASCA in Canberra.

Wijesekera - This seminar should outline a course of action.

Weerakoon - (Summing up)

We recommend that the Secretary-General of the National Science Council of Sri Lanka considers and urgently implements ways and means of encouraging research, training and gathering experience from other countries, especially in the field of sun-drying. The National Science Council of Sri Lanka is particular should arrange for :

1) Sufficient research grants for work in this area
2) Arranging travel fellowships
3) Arranging training scholarships

The seminar considering problems in solar drying recommends initiating action in the following areas (not in order of priority):-

Sun-drying

- Paddy (a) present methods
  (b) proposed methods
- Fish
- Coconut
- Rubber and by products of seed oil
- Subsidiary foods
- Spices
- Salt

Combination methods

Technical literature and solar absorber research

Dr. Wijesekera proposed a vote of thanks.

Types of Solar Dryers

Chamber Dryer - the material to be dried is placed in an enclosure.

Rack or Tray Dryer- the material to be dried is placed on an open rack or tray.

Sun or Natural Dryers - these dryers make use of the action of solar radiation, ambiant air temperature and relative humidity and wind velocity to achieve the drying process.

Solar Dryers - Direct - the material to be dried is placed in an enclosure, with a transparent cover or side panels. Heat is generated by absorption of solar radiation on the product itself as well as on the internal surfaces of the drying chamber. This heat evaporates the moisture from the drying product. In addition, it serves to heat and expand the air in the enclosure, causing the removal of this moisture by the circulation of air.

Solar Dryers - Mixed mode - the combined action of the solar radiation incident directly on the material to be dried and air pre-heated in a solar air-heater furnishes the heat required to complete the drying operation.

Solar Dryers - Indirect - the solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then ducted to the drying chamber, to dehydrate the product.

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