Invited Paper

FOOD PROCESSING INDUSTRY : ENERGY SUPPLY ALTERNATIVES

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Abstract- The importance of the food industry to a country's economy and the Energy-related problems faced by the industry are highlighted. The paper discusses the applicability of Chemical Engineering principles and concepts in arriving at solutions to these problems. The importance of adopting "Unit Operation" method widely used in the Chemical Industry, is seen to be specifically beneficial to the food industry. The enormous advances made and the techniques developed make it easy to adopt and utilise a vast amount of already available information. Possible Energy saving techniques in some unit operations frequently encountered in a food process are presented. Finally, planning and implementation of an Energy Management Policy is briefly discussed.

INTRODUCTION

The oil crisis the world faced in November 1973 awakened societies to an unpleasant reality. That year marked the end of an era of carefree use of energy resources. For a country who did not have an indigenous supply the ensuing period was very difficult. Sri Lanka, being one such nation, faced severe economic problems. Although fuel prices today have fallen from the dizzy heights they reached during the seventies, one cannot be complacent. The fact that the available resources are limited and dwindling fast must not be forgotten. It has to be remembered always that the use of energy is an expensive operation and needs careful planning and implementation.

Food holds a key position in the development of a country. The more self-sufficient the country is in food, the less is its vulnerability and the greater its independence. Improved use of energy throughout industry and commerce can make a significant contribution to the nation's economy and will make the user of such a practice more competitive. The correct practice can have a substantial and beneficial effect on other costs; labour , raw materials and capital can all be more effectively applied. In production, too, reject rates can fall, product quality can improve and the environment will benefit. The food industry, like any other, faces problems related to energy. This paper looks at the options available to the food processing sector and discusses the supply options and other alternatives with special reference to Sri Lanka.

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FOOD PROCESSING INDUSTRY

Food has been the mainstay of human society; processing of food has been with use for a long time. People long ago realised that times of plenty will be followed by times of famine and learnt to keep part of their output for such periods of scarcity. Also the consumer in general, is displaced both with respect to time and place with regard to the manufacturer and this necessitates the use of preservation techniques. Figure 1 gives the food chain through which food reaches the consumer. Food processing is involved in all stages as some form of processing is inevitable in the initial and final steps. In the chain, food processing is the most energy consuming sector . It has been estimated that approximately 1/3 of the Energy consumed within the chain is expended on food processing. Figure 2 gives the general structure of the food industry. The technological contribution towards food processing in recent years has been significant and the advent of new types of processing technologies is showing a tremendous impact on the food industry.

The Food industry is highly diversified, with process plants ranging from small plants to large industrial units. Sri Lanka is a developing country and the scale and structure of our food processing industry is not similar to those that can be observed in the developed world. Sri Lankan socio-economic climate influences the country's food industry. It is inevitable however considering the country's interaction with the outside world and its burgeoning population, that we will have to accept certain principles which are common in

FOOD CHAIN

HARVEST

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FOOD PROCESSING PLANT

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POINT OF RETAIL SALES

but broadly,

FOOD PROCESSING

SEPERATION

ASSEMBLY

PRESERVATION

and these operations can take place at any position along the food chain

Figure 1- The Food chain

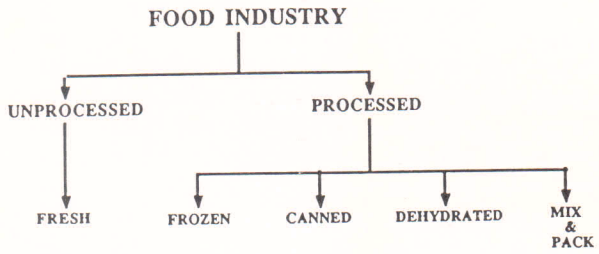

Figure 2- General structure of the food industry

the food processing industry of the developed world. This must be done with caution: It is said that the problems of food technology should be approached in general the same way world-wide. Yet a generalized approach does not exist. Each country should tackle the problem suitable to its own economic framework, and for a developing country like Sri Lanka, there are several important factors to be specifically borne in mind.

The Food industry must orient itself to make use of available resources rather than relying on imported material. Such an action minimises development-inhibiting consequences like reduction of work opportunities, increased dependence on foreign countries, destruction of local trade, deprivation of the population of traditional basic foods, increased costs etc. In addition, food technologies of the industrialized world are not directly transferable to third world countries, as those strategies are developed considering their own situations. Currently the food industry of industrialized countries is trying to eliminate jobs and not to create them.

For the sake of development, the health of the nation should not be neglected. The producers of food have a moral responsibility to society, and cost cutting and other improvements should not be at the expense of health. This has become a topical issue in the developed world as the manufacturers, in the quest to improve their profits, have instituted programs which have been clearly shown to affect the health of the consumers.

The aim of this paper is to examine energy supply and management in the food processing sector of Sri Lanka. The views presented here were formed during a 3 year Ph.D project in Cambridge University Chemical Engineering Department, in which I carried out a development study of a new food processing operation. This work enabled me to obtain both an insight into the food processing industry of a developed country, and much experience in the interaction between the food industry and Universities. In the UK, Chemical Engineering techniques are widely employed in the food industry, and the author feels that the Sri Lankan food industry also stands to benefit greatly by employing standard chemical engineering principles.

The food processing sector in Sri Lanka basically consists of small and medium scale industries. Few big industrial complexes are also present in sectors like dairy, biscuit, beverages and prepared animal feed. Also the factories like flour processing and sugar falls within the food sector. Being a mixed economy, state as well as private ownership exist within the industry.

Energy Usage

Sri Lanka lacks energy resources like coal, oil and natural gas and hence has to depend on outside sources. Because of this, the economy is very susceptible to external effects. Many countries have extensive ongoing research into alternative energy sources like nuclear, hydrogen energy, and on renewables like solar, wind, ocean thermal gradients, tidal and biomass. In these areas, there is lot of information interchange between countries. In developed countries nuclear energy

has became a viable option, but this is not yet valid for us at least in the short or medium term. Fortunately, the presence of hydroelectric power is a valuable asset to the country. The current Mahaweli diversion scheme will hopefully be able to boost the available supply, lessening the dependence on thermal power during peak hours. All industries including food, depend on electricity from the national grid and fossil fuels for motive power. Energy-related problems that will affect food processing can be broadly categorized in two main groups.

(1) Problems that will affect all industries in general.
(2) Problems specific to the food industry.

Obtaining solutions to group 1 problems are much easier, as there are more people looking into the problems; the food industry is able to use the solutions obtained by them. Group 2 poses more challenges, since the food industry is highly diverse, as even within various sectors many types of problems can arise. Here the food industry stands to benefit from the chemical industry. The chemical engineering concept of "unit operations" greatly benefited the chemical industry and put it on a more scientific footing. Chemical engineering principles can also provide the basis for more fundamental and quantitative understanding of food processes. It offers knowledge on transport phenomena, reaction engineering, phase equilibrium, thermodynamics and improved techniques of process synthesis, design and control. Food processing techniques that stand to benefit from such knowledge include drying and concentration, leaching and extraction, sterilization and enzyme deactivation, freezing and packaging. Figure 3 illustrates the importance of understanding the mechanisms of these processes. A Chemical Engineering approach presents the industry with many benefits. There have been many significant advances made in Chemical Engineering with regard to developing energy efficiency within unit operations. This knowledge can be directly tapped and be advantageously adapted to be used within the food industry.

Three major options are available to the industry. They are,

(a) use of an alternate supply of energy,
(b) efficient use of energy and
(c) re use of waste streams.

These three can further be considered under

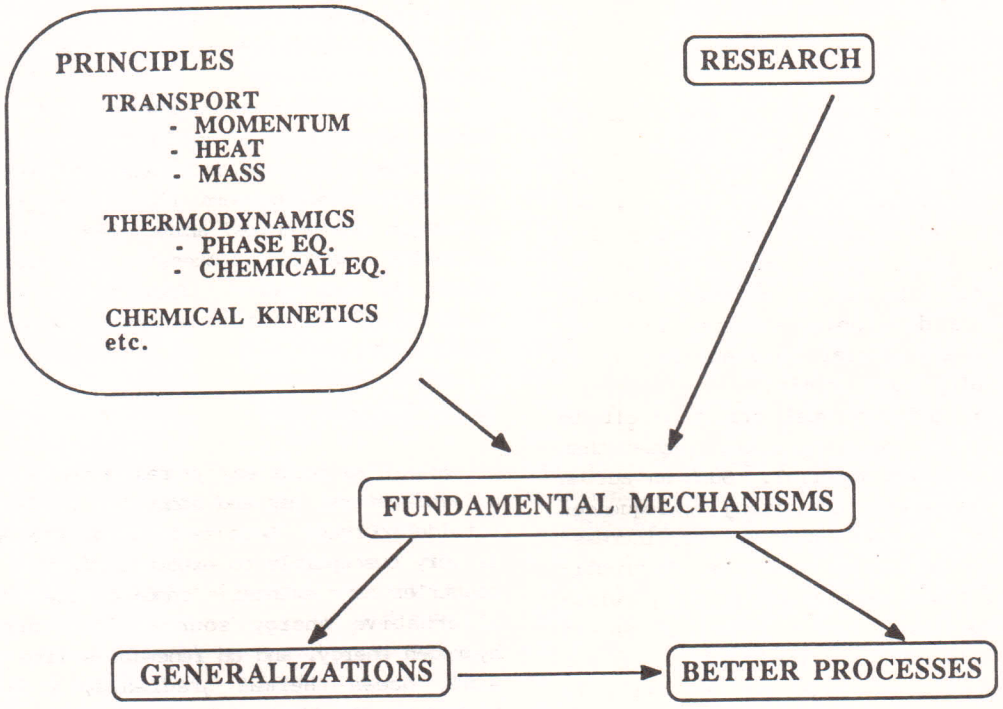

Figure 3- Importance of Understanding the mechanism

(a) Short term measures which can be rapidly put into effect and involve very little capital outlay.
(b) Medium term developments : which require, detailed appraisal of capital investment schemes, but use essentially well established technologies.
(c) Long term developments : Novel plant or processes. Requires development and proving of new technology. The benefits might not be felt for ten or more years.

What follows is a discussion on the available options. The discussion is not meant to be exhaustive but will provide some "Food for thought".

(a) Use of an alternative supply of Energy-

Considering this option,the question to be posed is- is it really possible for us to resort to alternate supplies at this stage ? If industry were to switch totally to an alternate supply, it should be consistent, reliable and cost effective. Sri Lanka has never undertaken major research and development work on a scale necessary to support such a move. At present, the economic climate does not warrant, nor does the infrastructure exist, to initiate major R & D movements from within the food industry. The food industry must thus rely on government initiated and supported work. So in the near future, the major shifts within the industry may be between the type of fossil fuel employed i.e., changing from oil to coal, increasing use of electricity etc. It is also possible to supplement conventional supply by using alternate means, the most feasible of which seems to be the use of biogas. Technology and expertise is available in Sri Lanka and some limited projects have been done : at Gannoruwa and Pattiyapola. Bio-gas is a highly combustible mixture of methane and carbon dioxide and can be used for cooking, lighting, refrigeration and as a substitute for diesel in a small engine. It is not always recognized that the most valuable feature of biogas generation is the fertilizer sludge which remains after the gas has gone and can be effectively employed in the agricultural sector. Industry stands to benefit more in the short term from biogas especially the small processing sector. Much information on biogas is available as it is the most widely used form of renewable energy in the third world.

The use of charcoal derived from wood is a possibility. Charcoal is lighter and more compact than raw wood and if the conversion process is effective, it is a possible source of energy. Care must be taken to avoid deforestation. It is sensible to use wood from land that is cleared to create new irrigated croplands, such as that associated with the Mahaweli scheme.

If cost effective drying is utilized, it is possible to make use of peat deposits in the short term. Peat, a low grade traditional fossil fuel, can be burnt, gassified and made to produce methanol.

The above discussion shows that the possibility of a major shift in energy supply for the food industry is unlikely in the near future. This means that in the short and medium terms, better energy management and the use of waste streams seem the best way of tackling energy problems.

(b) Efficient use of Energy- Is better energy management possible ?

The food processing industry, because of its long history, evolved more as an art than a science. Only recently has scientific understanding of processing begun, Engineering techniques like process optimisation and efficient control strategies are recent additions to the practice. There is much to be done with respect to improving the industry.

Energy management within the food industry :

The first step in any energy management scheme is to obtain a full picture of the usage of energy within the process. Energy accounting in the food processing industry is a useful way to obtain relevant information, that can be used for energy conservation and to improve energy use. There are various ways of obtaining and presenting data. The classical method in the chemical industry is to conduct balance calculations to gain an insight into the system. Balance calculations are computations based on the principles of conservation of mass and energy that serve to determine the flows, compositions and temperatures of all streams in a flow sheet.

Material balances highlight the amount of raw materials used and the conversion of it to the desired product. These highlight the efficiency of the process with respect to the product and does not directly infer its energy efficiency. It is persuasible to have process

routes with high conversion efficiencies but poor energy efficiencies. As all matter reprsents a form of energy, efficient use of material means efficient use of energy.

Energy balances provide an energy inventory of the system. It is an expression of the law of conservation of energy. The balances provide the user with an idea of energy interchange between the system and its surroundings between the initial and final states.

Another simple and efficient way of illustrating energy flows in terms of individual process needs and energy wastage is by means of a Sankey diagram, as illustrated in Figure 4. This offers an easily understood representation of the amounts of energy consumed and the scope available for improving energy efficiency.

A more recent approach is to do an energy and exergy analysis. This is because it is felt that energy and mass balances give only limited information of the efficiency of energy usage. Exergy is defined as energy, which through a reversible process, is totally tran-

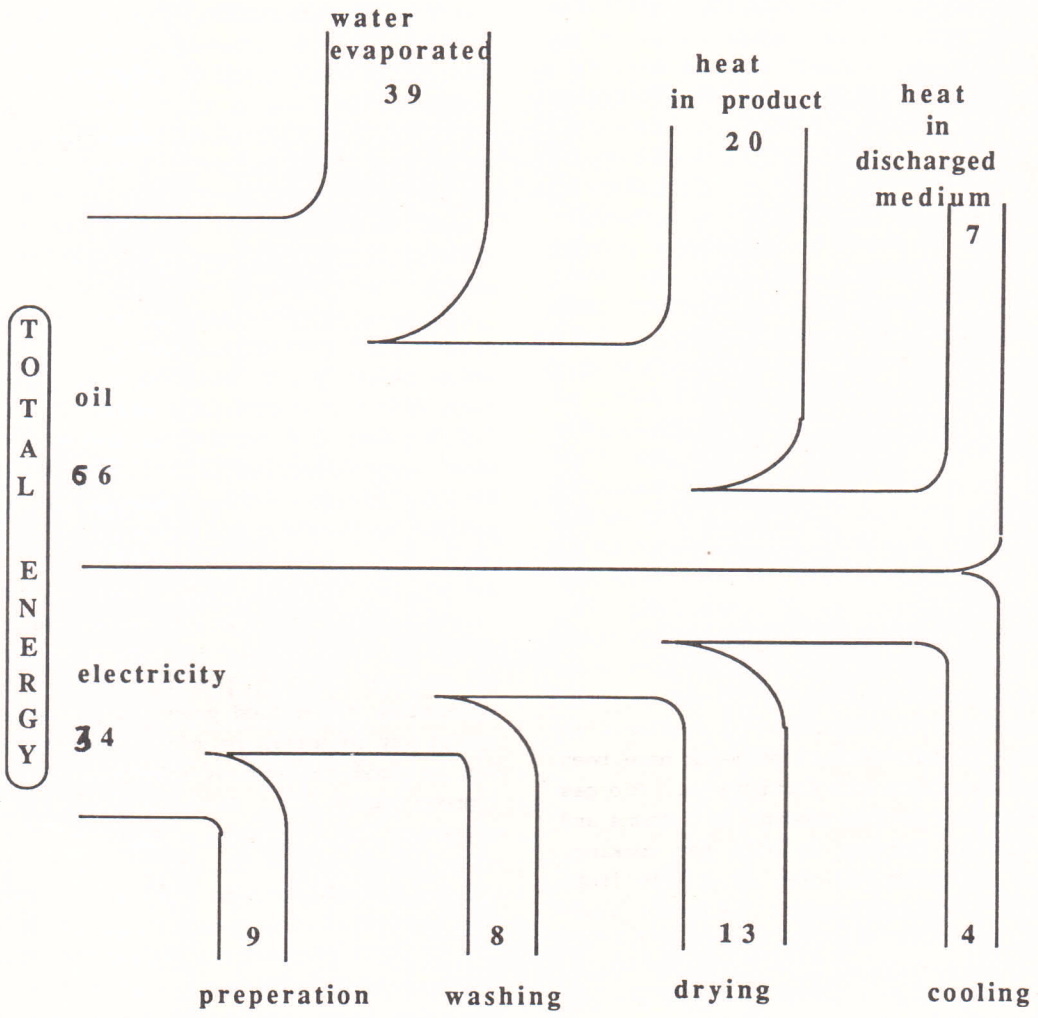

Figure 4- A Shankey diagram
(The example relates to a drying operation)

sferable from one kind to another. Another way to explain exergy is to say that it means the maximal technical capacity of work of a system for a given amount of energy. The use of energy is an attempt to make an "economic" evaluation of energy management in some selected food processing operations is presented in reference[1].

The following highlights some areas in the food processing industry where improvements can lead to better energy utilization.

Good house-keeping practice :

This an area where the techniques used in other industries can be directly or easily adapted to use within the food industry. Some of these are -

- check water usage regularly.
- reduce water temperature where possible.
- check operation of combustion processes and equipment to ensure good combustion without excess air usage;
- repair and/or replace deteriorated insulation;
- repair or replace leaking steam traps;
- minimize use of outside make-up air,
- turn off all process equipment when not in use;

Change of raw material used :

If an expensive raw material is used it may be possible to replace it with another. This specially should be done with raw materials for the supply of which you have to depend on foreign sources. As an example changing from wheat flour used in baking bread to another alternate raw material is a worthwhile goal as this has to be bought spending foreign exchange. The raw material can be effectively substituted and then gradually replaced by locally produced cereal crops.

Changing the final product:

If the final product is achieved through an energy intensive process and if it necessitates the employment of more energy intensive methods for its preservation and storage, the feasibility of replacing that product by another cost effective one should be considered.

For example, Asian and African countries following the route adopted in developed countries, produce pasteurised milk. The different climatic conditions prevalent in our countries require us to use energy intensive methods to change the product environment by cooling it. This costly method has to be used from the production site all the way down to the consumer. Yet it is possible to manufacture good sour milk with butterfat which is a more suitable product while also being cost effective.

The production method applied to the raw material:-

This is an area where major improvements are still possible. Food processing industry evolved as an art rather than as a science. For many years, food industry remained insulated from the development work going on in other industrial processes and this is to a certain extent true even today.

The best stage to consider the optimal production method is during the design stage. Yet certain modifications can still be incorporated into an existing installation depending on economical pay back periods. For instance, dehydration is a common unit operation widely used in food processing and can be implemented in many ways. This is effectively shown in Table 1. The proper selection from this multitude of options is vital as otherwise, gross inefficiency will result.

The adoption of the Chemical Engineering Unit Operation concept at this stage is very useful. The whole process is partitioned into units whereas in each of which, a desired chemical or physical change is being carried out. This individual approach narrows down the possibilities but the decision should finally be considered from an overall context. Some alternative methods available in a few selected unit operations, the adoption of which may increase energy efficiency, are highlighted.

(1) Evaporation:- Evaporators are used in dairy and sugar industries. There are several techniques for improving the efficiency of evaporators, but the most cost effective is often the use of mechanical vapour recompression (MVR). By compressing, the steam is driven off, and thus raising its temperature, it can be used as the heat source for driving the evaporation process. Increasing the number of effects is another possible way of improving efficiency.

(2) Drying :- Drying is an operation which uses a good deal of energy and is a common operation in food as well as in the chemical

Initial phase of water	Receiving phase of water	Means of lowering chemical potential of water in receiving phase	Example
I. Equilibration processes			
Liquid	Vapor	Vacuum (pressure)	Flash evaporation
		Superheat of Feed (temperature)	Drying with super-heated steam
		Carrier (composition)	Air drying
	Immiscible liquid	Solvent (composition)	Extraction
	Solid	Freeze (temperature)	Freeze concentration
		Precipitate (composition)	Clathrate processes
		Adsorb (composition)	
Solid	Vapor	Vacuum (pressure)	Ordinary freeze drying
		Carrier (composition)	Carrier-gas freeze drying
	Immiscible liquid	Solvent (composition)	
II. Rate-governed processes			
Liquid	Vapor	Vacuum (pressure)	Aroma retentive vacuum drying
		Superheat of feed (temperature)	
		Carrier (composition)	Pervaporation
	Liquid	Pressurize feed (pressure)	Reverse osmosis
		Added solute (composition)	Direct osmosis
		Solvent (composition)	Perstraction
III. Mechanical processes			
Liquid		Screening	Pulp removal
		Density difference	Centrifugation before evaporation of juices
Solid		Screening	Grinding of frozen solutions and pastes
		Density difference	Grinding of frozen solutions and pastes

Table 1. Different approaches to the separation of water from food material

industry. However, the conditions under which food such as milk can be dried are very different from those likely to be suitable for fertilizer, inorganic chemicals or paper. Nevertheless, it is still possible that some technical advances made in chemical industry can benefit the drying operations in the food industry. For example, in drying, energy can be reduced by prior dewatering steps, higher drying medium inlet temperatures and the use of counter current as opposed to co-current flow of product and drying medium. Use of new techniques like fluidised bed drying should be considered.

(3) Sterilization:- Overall energy requirements in pasteurization or sterilisation operations can be reduced by the use of regenerative systems such as some high temperature short-time (HTST) systems. Also the canning methods can be greatly modified to be more energy effective.

(4) Refrigeration:- Today freezing is a widely accepted unit operation in the food industry and is applied to many processed and unprocessed foods. Where extensive refrigeration is required, consideration should be given to the use of ammonia, which is thermodynamically more efficient than the freons.

Extent of utilization of the raw material:- The yield and selectivity of the process should be high. The raw material to product conversion ratio must be considered within the time scale in which the operation is carried out. To accelerate the rates of food processing operations, it is necessary to identify and understand the rate determining factors. Introduction of some processing steps during the initial raw material preparation can enhance the process. If the raw material contains some impurities or non reacting parts, an initial separation process can be carried out. This will increase the throughput of the process.

The type of energy used for transport, service supplies and storage and packaging:-

During the processing of foods, in addition to the energy utilized in processing, energy is also used in cleaning, packaging, stora.pa ge and transport. Considerable amounts of power are needed for food storage, particularly fresh meats and frozen foods, and sanitation. Cleaning and sanitation aspects of food processing are very important. In developed countries cleaning in food industries is big business, the estimated world sales potential of chemicals being well over a billion dollars. The selected cleaning methodology is very important in reducing costs. Cleaning

techniques can be modified by using lower t,temperature techniques and/or through the use of clean-in-place (CIP) systems, and of course, using the absolute minimum of water.

Packaging material should be cost effective. In principle, one could use a tin can, a glass bottle, a plastic container or even a waxed cardboard carton for holding a variety of consumable liquids. In the long term, if energy prices rise very much in real terms compared with other resources, then one or the other of these methods of packaging might emerge as a front runner. The packaging material in some instances should be able to be reused. i.e., glass bottles used in the milk and beverages industry. If paper cartons are used there is no possibility of straight recycling hence when considered in total glass, can edge out paper as the packaging material in most cases except in the convenience-food sector. Also, recycling of the packaging material will reduce adverse environmental effects.

The presence of a distributed food industry means the distribution costs tend to be lower. The transportation of bulk-produced goods from a big manufacturer to retailers should be done economically. As a developing country, we need not resort to means such as big fleets of trucks but should try to rely more on the national transport network. Transportation using the railway network is a more cost effective method.

(c) Utilisation of waste streams:-

In all production processes waste streams result. Wastes are becoming an increasingly attractive fuel option since their incineration and heat recovery not only solves a disposal problem but produces energy.

For instance in the sugar industry, Bagasse, the crushed sugar cane after the sugar has been extracted, can be converted to high quality charcoal or burnt directly. In some large sugar factories the only external energy utilized within the plant is for lighting since the Bagasse resulting from cane crushing is burned directly to produce steam. This steam operates the evaporators and steam turbines, which are used as prime movers to drive pumps and centrifugals. Also efficient energy recovery may be done with efficient use of waste streams. In the milk processing industry, with evaporation of milk products, any process site is left with an excess of condensate.

There are three kinds of waste streams: i.e., clean, milk contaminated and dirty. It may be possible to make use of these various streams. Also, in the edible oil industry, after extracting oil through the process pf expelling and solvent extraction, the remainder from the raw material can serve as a good basis for animal feed. process of expelling and solvent extraction, the remainder from the raw material can serve as a good basis for animal feed.

Heat recovery system can be very effective in boiler operations and also if a hot products stream are going out, they can be made to exchange heat with the incoming cold streams. A means of conserving energy in boiler operations involves the return of the condensate to the boilers. It has been estimated that up to 10% of the heat required for steam generation can be recovered in this way.

PLANNING AND IMPLEMENTATION

Availability of options has to be followed by action implementation to make them work. The management within the industry has more responsibility when it comes to this stage. Monitoring and constant assessment is a vital part of any implemented scheme. This gives a feedback of the effectiveness of individual actions implemented. Monitoring can be done in two fronts.

(a) Use of measuring instruments:-

The old management concept of spending money on instruments is not worthy as it is not productive, and should be discarded. The regular taking of meter readings and relating these with the process can highlight the effectiveness of the measures or point out the deficiencies.

(b) Personnel involvement

Process operators can derive better job satisfaction if they are given more responsibilities and also if incentives are given for the achievement of targets.

Recently in organisations a position of "Energy Manager" has been created to deal with matters concerning such schemes. The energy manager will be the focal point for records of energy use and the person directly responsible for their analysis. He must also demonstrate

that any data collected and provided by other people is not wasted. For small industries creation of a such a position may not be feasible, yet the management should see to that, they make proper evaluations of the process continuously. It should be realised that information is a vital in saving energy. The key objectives for an energy manager is given in Table 2.

1. Develop and maintain an energy accounting or audit system.
2. Co-ordinate the efforts of all energy users in the organisation helping them from a source of sound information to set tough but realistic targets.
3. Provide sound technical and specialist advice to all departments within the organisation on energy-saving equipment and techniques to promote the efficient use of energy.
4. Liaise with committees and working groups within the industry / sector and maintain contact with appropriate research organisations,professional bodies and government organisations to monitor, assess and apply all significant developments in the field of energy conservation.
5. Appraise and advice upon government funding and other schemes applicable to the organisation.
6. Examine, appraise and advice upon any political, legislative and regulatory measures relating to energy and assess the possible impact on the organisation's products and activities.
7. Remain up-to-date on the changing world and national developments on energy matters and advice senior management of the possible effects on the organisation.

Table 2- Key objectives of an Energy Manager

Most energy saving concepts involve extra equipment and thereby additional capital costs. The Government can help the small scale producer by contributing part of the capital costs to projects demonstrating some saving of energy. Also energy audit schemes run by the government can look at sections of industry in much greater depth and advice on improvement to be done to bring about savings.

CONCLUSIONS

It can be said in conclusion that the solutions to problems facing the food processing industry in Sri Lanka should be considered more on a national scale as developments within this sector will be directly felt by the consumer as well as boosting the national economy. Also this national approach will benefit the small and medium scale producer as they, in general, are not in a position to indulge in experimentation except on short term measures.

Measures should be taken to build up a suitable industry-university interface as this, to a large extent is lacking in Sri Lanka. Universities are more academically oriented and the expertise created and contained within it should be profitably used in solving national problems. The policy of utilising foreign consultancy services to solve national ills should be cut down. Except in certain cases the widespread conviction that development can be achieved with the purchase of modern technologies is false. It only leads to an illusion of development. Real development can only grow on local soil. Food Processing is no exception.

While utilising the available resources it is also important to build up the technical personnel necessary to serve the food processing industry. At present in Sri Lanka courses, in Food Science are available. To help in technological problems people with necessary technological skills are lacking. Universities at present do not have courses leading to degrees in food process engineering. There are courses leading to diplomas in food technology but heavily science oriented. It is best at present to utilise the skills available in Chemical Engineering at this stage. In developed countries it is recognised that what the food industry needs is the breadth of the food scientist and the depth of the Chemical Engineer. With some small changes in the present curriculum in Chemical Engineering it is possible to obtain specialised personnel to serve the technological needs of the Sri Lankan food processing industry.

Finally the world was caught unawared in 1973. We cannot afford to do the same mistake again. It is essential to try to maximise the benefit the society receives from using its energy supply. The supply should be used wisely and economically. The future predictions regarding energy should be given careful thought. It is better to bear in mind that with regard to Energy. "He who says he knows future lies, even though he may tell the truth"

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