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SCIENCE EDUCATION SERIES

No. 4

FOOD SPOILAGE AND FOOD PRESERVATION  
IN SRI LANKA

*by*

Mervyn W. Pulle, B.Sc., Ph.D.

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NATIONAL SCIENCE COUNCIL OF SRI LANKA

47/5 Maitland Place

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## FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the National Science Council. The National Science Council Journal provides a medium for the publication of scientific research papers, while "Vidurava," the quarterly science bulletin of the National Science Council, contains scientific articles of a general nature which are of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Science Education Research Committee (SERC) of the National Science Council decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and not necessarily those of the National Science Council.

In conclusion I must thank the Science Education Research Committee of the National Science Council, and in particular its Hon'y. Director, Prof. K. Jayasena, for the work they have put in to make this project a success.

**R. P. Jayewardene**  
*Secretary-General*  
National Science Council of Sri Lanka

14 November, 1980.

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## Chapter 1

### INTRODUCTION

All foods used for human consumption are perishable commodities. Food obtained from plant sources commence deterioration from harvest and animal foods from the moment of slaughter. In addition to these raw foods, it is observed that even prepared food items perish with time. Depending upon the food this deterioration may be very slow as in the case of seeds or nuts while it may be rapid as in fish or meat so as to render the food useless in a matter of hours.

In a broad sense a food is considered spoilt when it is no longer fit for human consumption. This definition includes a wide range of conditions such as foods that (a) have become rotten (b) have lost their nutritional value (c) look bad enough to avoid eating them, or (d) when consumed will result in health hazards giving rise to food-borne diseases and food poisoning.

#### **Food losses**

Food spoilage is directly related to food losses. Thus, it is a very serious problem since it does not make available to us all the food that is produced. In other words to make best use of the food production efforts both in Sri Lanka and the world over it is of paramount importance to eliminate or reduce the large losses due to food spoilage.

The useful storage life of some foods when proper control measures are not taken is given in Table 1. It is noticed from the table that if foods are stored at room temperature, meats and leafy vegetables spoil within 1-2 days and only cereal grains could be kept for a long period. This information is applicable to our situation as deterioration is more rapid because of the tropical climatic conditions. Factors such as restricted transport from the field, improper storage at sales points in the retail markets and overall sanitary conditions further affect food spoilage.

**Table I Useful storage life of some foods**

<b>Food</b>		<b>Average storage life (days)</b>
Animal flesh, including poultry	..	1 — 2
Dried fruits	..	360 and more
Dried, salted or smoked meat and fish	..	360 and more
Dried seeds	..	360 and more
<b>Fish</b>	..	1 — 2
Fruits	..	1 — 7
Leafy vegetables	..	1 — 2
Root crops	..	7 — 20

The obvious loss from food spoilage is that it reduces the total food supplies in the country. However, considering that food is consumed not only to satisfy hunger but also to obtain valuable nutrients for our health and well being, the nutritional damage caused by food spoilage is of concern. Nutrients in spoilt food are lost by destruction, fractionation or chemical inactivation. In addition harmful substances develop within spoilt foods which can affect the health of the individual.

## Chapter 2

### CAUSES OF FOOD SPOILAGE

Spoilage of food occurs from a number of factors and the major causes of spoilage are indicated in Table II. Although these causes are listed separately it is known that they are not isolated in nature. At a particular time many forms of deterioration may take place depending upon the food and the environmental conditions. In most cases quite a number of these factors create the final result of food spoilage, while in others the effect of any one of them may pave the way for other factors to have a more pronounced effect on the food. For example, beef exposed for sale in the meat stall may spoil because of high temperature, unhygienic conditions or enzyme and microbial action, all causes acting at the same time. On the other hand moisture in food will facilitate the growth of spoilage causing microorganisms. In order to appreciate the spoilage characteristics in various foods it is necessary to be familiar with these causes so that proper control measures can be adopted to eliminate or reduce food spoilage.

Table II Major causes of food spoilage

Sources	Causes	Factors
Internal	Microbiological	Bacteria, molds, yeasts
	Chemical	Enzymes, metals
	Physical	Oxygen, temperature, moisture, Relative Humidity
External	Rodents	Food consumption, excreta, hair
	Insects	Food consumption, fragments
	Agrochemicals	Insecticides, weedicides, fungicides

#### Spoilage by Microorganisms

Among the causative factors, the damage done by microorganisms could be easily singled out as the most common cause of food spoilage. All living organisms require food for their growth activities and as such compete with man for the nutrients found in food. Under improper storage or handling conditions large numbers of microorganisms readily invade food utilizing the nutrients while leaving behind a range of damage

characteristics. Quite often the food may change colour and produce an undesirable odour. A normally solid food may become a smelly liquid, while the reverse may happen with a liquid food. Milk for example becomes rubbery or stringy as can be seen in fluid or sweetened condensed milk. These damaged foods can be easily recognized by us and the undesirable changes can help in avoiding spoilt foods. However, some changes caused by microorganisms though quite harmful may be unnoticed until it is too late and often serious complications arise only after the food is eaten. Living microorganisms in food cause various sicknesses if we ingest them and are unable to control their growth within our bodies. Food-borne bacterial infections can generate digestive disorders, high fevers and create a lot of discomfort. The bacterium *Clostridium botulinum* may contaminate food and remain virtually invisible but many deaths have been reported as a result of the poisonous substances produced by this microorganism.

### Types of microorganisms

Let us examine the nature and types of microorganisms that can cause food spoilage. As the term suggests these refer to minute or extremely small living organisms that could be seen only with the aid of a microscope. Considering their small size, the unit of measurement is the micron ( $\mu$ ) which is  $10^{-6}$ cm. Usually the dimensions of a bacterium range from  $0.5 - 1.0 \mu$  to  $2.0 - 5.0 \mu$ .

The study of Microbiology is devoted to the growth and activities of the several thousand species of microorganisms which are universally present in nature. Although there are many groups of microorganisms those which are important in food spoilage are included in the Bacteria, Molds and Yeasts. Figure 1 shows illustrations of some of these microorganisms.

*Bacteria* are unicellular microorganisms with one of three characteristic forms namely (a) ellipsoidal or spherical (b) cylindrical or rod-like and (c) spiral or helical. In fact the individual names of bacteria follow their form or shape; coccus/cocci (singular/plural) refers to spherical bacteria and bacillus/bacilli to rod-shaped organisms. The names of some common bacteria such as *Streptococcus* and *Lactobacillus* indicate spherical and rod shaped bacteria respectively.

Figure 1 Types of Microorganisms

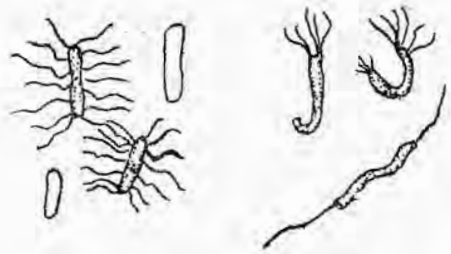
A. Bacteria



Streptococcus



Micrococcus



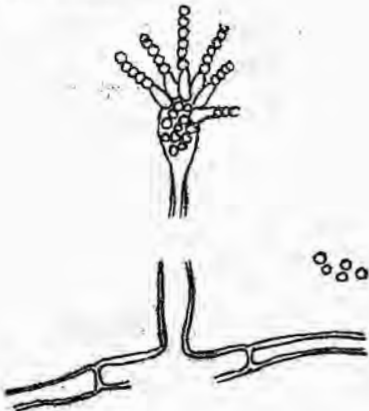
Rods or Bacilli and Spiral types

B. Yeast

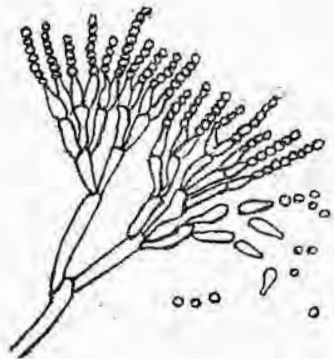


Saccharomyces spp.

C. Molds



Aspergillus spp.



Penicillium spp.

*Molds* are multicellular microorganisms which are strictly lower plants devoid of chlorophyll. In size they are quite variable ranging from microscopic to visible masses of filaments such as the cottony growth noticed on stale bread. Molds are usually found on the surface of foods as they require oxygen for their growth.

*Yeasts* resemble the spherical bacteria but are much larger in size measuring about 20  $\mu$ . They are commonly egg shaped and are found growing on high sugar media.

### **Growth characteristics**

Members of all three groups of microorganisms are widely distributed occurring in every conceivable part of the environment such as soil, water, air, utensils, plants, insects and animals. Hence they could readily invade food grow and multiply rapidly resulting in thousands of microorganisms within a short time. The multiplication of bacteria at room temperature is represented in Table III to give an idea of the extremely large numbers that are produced within a 72 hour period.

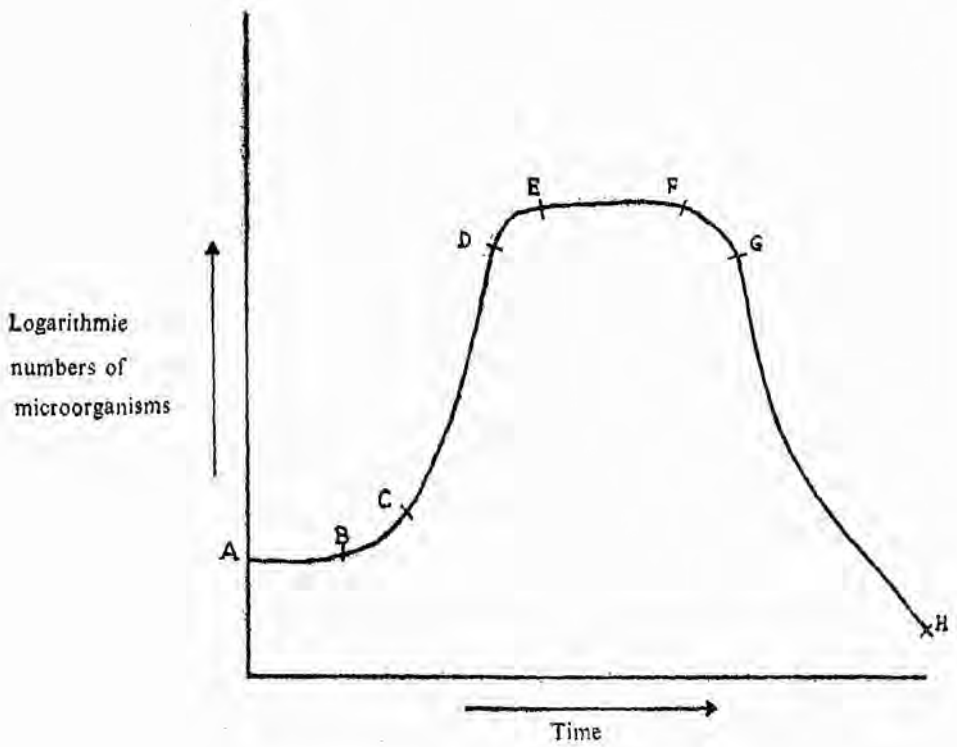
In order to arrest the phenomenal increase in microbial numbers it is of interest to know the rapidity with which they grow and multiply. This is best represented by means of a growth curve (Figure 2) from which it is possible to determine at what stage growth must be stopped to avoid subsequent increases in the microbial population. In Figure 2 the logarithm of the number of microorganisms is plotted against time

**Table III Multiplication of bacteria at room temperature\***

Storage period (hours)	Bacterial count per ml
0	137,000
24	24,674,000
48	639,885,000
72	2,407,083,000

\*Bacterial numbers reported are for beef muscle

Figure 2 Growth curve of microorganisms



- A - B: Lag phase
- B - C: Initial growth phase
- C - D: Logarithmic growth phase
- D - E: Negative acceleration
- E - F: Maximum stationary phase
- F - G: Accelerated death phase
- G - H: Death phase

showing the typical growth pattern of microorganisms. There are a number of growth phases in this illustration. During the initial phase the microorganisms are getting used to their environment and may even decline in numbers. Then follows the actual growth phase where the microbial population first increases in a linear order and proceeds to the accelerated growth phase where logarithmic increases are obtained. On reaching maximum addition to the microbial population a stationary phase is found where the new microorganisms added are just enough to replace those that die. The final phase is called the decline or death phase where the microbial population gradually reduces because they have fully exhausted the nutrients in the food. The important conclusion to draw from this diagram is that any type of control measure should be designed so as to prevent microorganisms entering the accelerated growth phase. It is seen that always a certain number of microorganisms occur in food but only preventive steps taken very early will arrest their growth before it reaches a stage when the desired control would not be effected since deterioration has already proceeded in the food.

#### Requirements of microorganisms

Microbial growth follows the trend shown in Figure 2 only if their requirements are provided. Under these circumstances the microbial populations that invade food will increase enormously, use the nutrients and cause spoilage of food. Thus an important consideration in preventing food spoilage would be the knowledge concerning the growth requirements of microorganisms. Bacteria, molds and yeasts have different requirements and these are summarized in Table IV. The requirements are both nutritional i.e. supply of proper nutrients and environmental where the conditions of the food such as temperature, moisture content and pH should be favourable for growth of particular types of microorganisms.

**Table IV Major requirements of spoilage microorganisms**

Requirement	Bacteria	Molds	Yeasts
Moisture	+	+	+
Oxygen	+ or -	+	+
Temperature (C)	7-55C	25-30C	25-30C
pH	4-7	2-8	4-4.5

## Preventive measures

All the means used to control microorganisms centre on destroying and attacking them where they are vulnerable. For instance it is known that microorganisms need water to survive. Thus one means of control is to remove as much water as possible from the food product. This is often done by a dehydration process to prevent spoilage. Food such as Lakspray are dried products. However, dehydration is not done with many of our foods, and in such cases other control measures must be adopted to reduce food spoilage.

From the requirements of microorganisms it is found that each type has certain needs and tolerances for acids and bases. When a specific microorganism threatens food, an easy control measure would be to adjust the pH of the food in such a manner that the microorganism cannot survive. But making a food acidic or basic when it is normally not so, often changes flavour and texture making it unacceptable. Further, some microorganisms are not affected by acids and bases and can tolerate wide pH ranges.

When dehydration and pH changes are not possible or fail, there are several other control measures. Most microorganisms need oxygen to survive and the obvious control is to eliminate oxygen from the environment of the food. This is a means of perfect control except that it does not eliminate those microorganisms which can survive and multiply in the total absence of oxygen such as the harmful *Clostridium botulinum*. Temperature control works well in controlling microorganisms, but in this case also there are some that can survive the most extreme conditions. Apart from this, certain microorganisms can remain in a dormant state and begin to grow as soon as temperatures become favourable again. Another approach would be to add growth inhibiting substances that will at least prevent spoilage although they do not totally destroy the microorganisms. These substances may however be toxic to human beings and should be used with caution.

Most often in the area of food science it is established that control of all spoilage microorganisms can be achieved by using the above measures in combination. Even if one or the other measure would not afford control if used alone, a combination method usually gives satisfactory protection for long storage of food products.

## **Chemical Spoilage**

Organic and inorganic compounds induce a great extent of food spoilage. It has been shown that chemical reactions in a food may be catalysed by enzymes or inorganic chemicals. Enzymic activity in food is pronounced resulting in the breakdown of various components such as carbohydrates, proteins and fats. Associated with this, certain undesirable changes occur in food with the production of off-flavours and off-colours. A very noticeable instance of enzymic activity takes place in fatty foods such as butter or coconut oil and this results in rancidity which gives a peculiar odour as obtained in stale coconut oil.

The proteins in meat or fish undergo putrefaction or spoilage and sometimes may produce harmful substances. In addition to those enzymes present in food, microorganisms also have the capacity to produce enzymes and the presence of microorganisms may result in further damage to the food. When conditions are suitable, enzymic activity results and effective control of these factors is necessary to prevent food spoilage. Most raw foods contain a variety of microorganisms and enzymes and considering the extent of the damage caused, these two factors are generally recognized as the main causes of food spoilage.

Inorganic chemicals contribute to food spoilage in two ways either by combination with food components or by functioning as catalysts in the enzyme processes that lead to spoilage. In both cases undesirable changes occur especially with the formation of abnormal colours. The blackening of canned foods may result from the production of iron sulphides. Contamination by metals can be satisfactorily avoided by using inert containers or wrapping material.

## **Physical Spoilage**

The environment of a particular food is greatly influenced by physical conditions such as temperature, light, air and Relative Humidity. It is quite evident that food spoils faster when stored at room temperature than when it is placed in the refrigerator. Also food in an open container is more vulnerable than that kept in a sealed jar. These instances show that low temperature and exclusion of air permit food to be stored for a longer period.

In effect these physical factors do not by themselves result in food spoilage. They are more specifically responsible for providing a suitable environment or condition in the food to favour microbial and enzymic

activity. Enzymes, like microorganisms, have certain conditions for enhanced activity. Hence control of the environment is essential to reduce the activity of the two main causes of food spoilage namely microorganisms and enzymes.

### **Spoilage by external sources**

The final causative factor of food spoilage is contamination of food by external sources. Rodents and insects bring about the greatest extent of this type of spoilage. This is an extremely serious problem since large quantities of food are continuously destroyed especially in bulk storage places and food stores. The Food and Agriculture Organization (FAO) has shown that the rat problem is particularly serious in India and other Asian countries where the population of rats is estimated to be about one rat for every three people living in these countries. A single rat would consume or contaminate 10 kg of food and the cumulative effect is the destruction of a large proportion of food available to our people. The rats, while consuming the food, contaminate it with hair, excreta and other substances especially in the case of cereal grains and flour. The quality of the product, especially flour, is greatly reduced as a result of attack by rodents and by insects such as weevils.

High humidity and temperature favour the rapid multiplication of rats and insects. Thus, considerable quantitative and qualitative losses occur to food grains. Studies done in Sri Lanka have shown that food grain losses in this country which range from 20 to 30 per cent are due to defective storage, handling, transport, packaging and the like. Such enormous losses occur primarily because of the inability to effectively control physical and biological factors. In addition the majority of our farmers still believe that spontaneous growth of rats and insects in food grains is a natural phenomenon and nothing can be done at their level to deal with this serious problem. It is also here that most of the damage to quality takes place. The adoption by the farmer of efficient methods of storage can result in more money being available to him besides serving the national cause of providing wholesome food to the consumer.

Another instance of contamination is through agro-chemicals which are sprayed or introduced to crops or animals for various reasons and have residual effects on food. Many foods are either spoiled or become hazardous because of contamination by antibiotics, insecticides, weedicides or other chemicals used in agriculture. The seriousness of the problem has been recognized by some countries and tolerances or limits of agro-chemical residues in food have been set for more common contaminants. The revision or necessary changes to the Food and Drug Act of Sri Lanka are needed to introduce strict legal measures so that contamination of food is eliminated enabling our foods to be safe for human consumption.

## Chapter 3

### SPOILAGE CHARACTERISTICS IN VARIOUS FOOD PRODUCTS

Perhaps the easiest way to discuss the spoilage occurring in various food products is to categorize them into specific groups. All the food consumed by us could fall into eight groups within the two main food sources. Typical examples in each of the food groups obtained from plant and animal sources are given in Table V. It is seen that each of these food groups has certain spoilage characteristics associated with it which are particular to the whole group.

Table V Typical examples of foods in various groups obtained from plant and animal sources

<i>Source</i>	<i>Food Group</i>	<i>Typical foods</i>
<b>Plant</b>	Cereal and cereal products	Rice, maize, sorghum, kurakkan, wheat flour, bread, buns, hoppers, string hoppers.
	Vegetables and vegetable products	Beans, carrots, spinach, pickles.
	Fruits and fruit products	Mangoes, avocados, pineapple, fruit drinks, cordials, jams, jellies, wines.
	Sugar and sugar products	White and brown sugar, honey, syrup, jaggery.
<b>Animal</b>	Meat and meat products	Beef, mutton, pork, sausage, ham, bacon.
	Fish and sea food	Seer, mullet, tuna, prawns, crabs.
	Poultry and eggs	Chicken, turkey, game birds and their eggs.
	Milk and milk products	Pasteurized and sterilized milks, butter, curd, cheese, yoghurt, fermented milks.

#### Cereal and cereal product spoilage

Rice, maize, sorghum and kurakkan comprise the main cereals consumed in Sri Lanka. Cereal products include flours such as rice and wheat flour bread, buns, hoppers, string hoppers, rotti, pittu, cakes and other bakery products.

For years, harvested paddy has been adequately dried by our farmers before long storage. In effect, the drying of paddy reduces the moisture content to less than 13 per cent so that microbial growth is halted. However inadequate drying or improper storage conditions such as exposure

to rain or moisture would facilitate the growth of molds. Under these conditions microorganisms found in the environment and the natural flora of the harvested grains readily grow and a mold cover could be noticed on the exposed surface. The mold types chiefly found growing are *Aspergillus*, *Alternaria* and *Cladosporium* species.

When cereal grains are stored in large bulk especially in conditions experienced in the Dry Zone, the high temperatures increase enzyme activity breaking down some of the starch in the grain to sugars and the proteins to simple nitrogenous substances. The fermentation of the sugars takes place resulting in the production of heat which destroys valuable nutrients in the grain. Usually this type of damage is not very marked when compared with the quantitative and qualitative losses brought about by contamination by rodents, insects and chemicals. Although not related to actual food spoilage, the stored grains begin to germinate when there are suitable conditions thereby reducing the total quantity available to the consumer.

Cereal flours forms the foundation ingredient for most cereal products in this case the big problem is rodent and insect attack. The number of microorganisms vary widely from a few hundred per gram to millions. Many samples of wheat flour taken from retail markets in Colombo, Kandy and other areas gave counts ranging from 50 – 100 mold spores. Storing flour in gunny bags is not the ideal since it permits the entry of not only microorganisms, moisture and air but also vapours and contaminants from other products if common storage facilities are used as seen in most of our retail stores.

The surface of a freshly baked loaf of bread or prepared bakery product is practically free of microorganisms because of the high baking or cooking temperatures. However these food items are subjected to contamination by microbial spores from the air and also from the surface of the knife during slicing or cutting. Molds are the most common cause of spoilage of bread and other bakery products. Bread is not usually kept long at bakeries before sale, but if left for a few days it can be spoilt by the "Bread mold" — *Rhizopus nigricans*. This is very evident because of the white and black fluffy appearance. Wrapping bread in plastic bags or filmed paper can reduce the mold damage. In the home this could be avoided by the use of a bread box stored in a cool, dry place.

Often the comment is made that bread and other cereal products become "stale". This is the deterioration caused mostly by physical changes when bread becomes dry and loses its taste and texture. In a reverse situation, highly moist cereal products can become stringy or ropy. This condition sometimes occurs in the "Dough" which is the ingredient mixture kept for a time before baking or cooking and is caused by bacteria of the *Bacillus* type. Strict hygiene of utensils, environment and personnel must be maintained to avoid this condition.

### **Fruit and vegetable spoilage**

Fruits and vegetables can be discussed together as they have many similarities with regard to their composition, methods of cultivation, harvesting, storage properties and processing. On the farm when fruits and vegetables mature they change from day to day reaching a peak quality at which time they are ready for harvest. Often we fail to realise that harvested produce is in a living state which means that respiration continues for a while giving off carbon dioxide, water and heat which influence the decomposition characteristics of fruits and vegetables.

Post-harvest losses are greatest in fruits and vegetables. Studies done in the University of Sri Lanka conclusively show that from the time of harvest till they reach the table 30 - 40 per cent of losses are obtained in the more degradable products. When one thinks of tomato for example it is very easy to recognize to what extent spoilage is observed in this product. Variety and type of product thus have a marked influence on the spoilage of fruits and vegetables. Harvesting at the proper stage is vital. Late harvests have adverse effects as the produce is already in the process of decomposition before steps such as packing, transportation and processing are taken.

Many different microorganisms attack fruits and vegetables, some causing quick decay and others first causing off-tastes. Injury to produce initiates and accelerates deterioration. An undamaged fruit is usually a hermetically sealed package, which means that it is sterile with respect to microorganisms. When the outer skin is damaged the path is open to attack by bacteria, molds and yeasts. Microbial damage may be due to (a) plant pathogens acting on the plant as well as on the edible portions (b) saprophytic organisms which are really secondary invaders entering the produce after the pathogenic attack. Although each fruit or vegetable has a certain type of decomposition pattern and has certain species

of microorganisms which are generally responsible for its spoilage, there are some general types of microbial spoilage that are found more often in fruits and vegetables than in other foods. These are the different kinds of "rots" caused by various bacteria and molds. Some of the numerous types are Bacterial Soft Rot (*Erwinia* spp), Blue Mold Rot (*Penicillium*), Black Rot (*Alternaria* spp) and Pink Mold Rot (*Trichothecium* spp). Along with these conditions there occurs Downy mildew (*Phytophthora* spp) and sliminess or souring (saprophytic bacteria).

Thorough washing of fruits and vegetables after harvest would help to remove microorganisms and dirt that stick to the surface. Otherwise by invasion of microorganisms not only rotting but breakdown of food components takes place. Starch and sugar change from their original form and due to continued activity a state of decomposition is reached when the produce is completely useless for human consumption.

Vegetables, especially the leafy types, do not on the average stay fresh for more than 2-3 days. Thus, considering their highly degradable nature some type of processing is necessary to prevent spoilage during prolonged storage. Fruits and vegetables are processed into various forms such as canned products, juices, cordials and fermented pickles, and other products. Although an extended storage life is assured, yet because of improper techniques even these products could eventually spoil. Fruit juices may undergo an alcoholic fermentation by yeast and further decompose to acids in the presence of bacteria. Canned products show a variety of spoilage characteristics if proper processing is not done and these may include acid production, gas formation blackening and also putrefaction.

#### **Sugar and sugar product spoilage**

White or brown sugar which is used daily in the home is mainly sucrose. Sugar products are honey, syrups, chocolates and the assorted types of sweets and candies.

Sugar available in the market is very low in total microorganisms. For the most part bacterial spore counts of a few hundred to several thousands/gm are obtained. Little or no spoilage occurs in sugar because it is normally kept dry enough to prevent the growth of microorganisms. Even when moisture is present and bacteria invade, they are unable to survive because the highly concentrated sugar solution draws moisture away

from them and they soon perish. It is only when moisture dilutes the sugar enough to prevent moisture withdrawal, that bacteria can commence to grow and increase in number. During the process of manufacture of sugar the original sugar cane or sugar beet juice becomes progressively purified and the purer the product the more unfavourable it is for the growth of microorganisms.

Although the sugar content is high in sugar products, depending on the cleanliness in preparation and storage, there is a possibility of some degree of spoilage. The chief microbial invaders are the yeasts of the *Saccharomyces* and *Candida* species having a preference for sugar and fermenting it into alcohol. Bacteria then complete the decomposition process to give different acids, chiefly acetic acid produced by *Acetobacter aceti*. Syrups exposed to air will in time be contaminated by *Aspergillus* and *Penicillium* species. These could be seen on the surface of bottled treacle or honey if any residual air is left before sealing.

As a result of the high moisture content in jaggery, molds may develop on exposure to air. Most sweets and candies are not subjected to microbial spoilage because of the high sugar and low moisture contents. However the exceptions are the soft-centre or cream-filled chocolates which under certain conditions burst or explode because of the high gas pressure developed from the growth of yeasts.

#### **Meat and meat product spoilage**

This category of high protein foods includes the skeletal tissues or flesh of cattle, goats, swine and other animals. Meat products used to a limited extent in Sri Lanka are bacon, ham, sausage and cured and salted products. The healthy inner flesh of meats is virtually free of microorganisms and spoilage results through external agencies during bleeding, handling and processing. During slaughter and cutting, microorganisms from the hide and intestinal tract of the animal gain entry into meat and the valuable nutrients are rapidly decomposed.

Meats spoil easily and some of this spoilage may go unnoticed even when detailed inspections are made. When exposed to air as in our open meat stalls, a slime can form on the surface. It is generally caused by *Pseudomonas*, *Achromobacter*, *Mucor*, *Thamnidium* and other species of microorganisms. Bacteria also produce undesirable colour changes and off-tastes called "taints." Meat pigments may change to brown-black and even green. In addition, pigmented bacteria (*Pseudomonas*,

*Flavobacterium* spp) may cause various coloured spots on meats. Because of these changes, meats appear quite unattractive and are usually not consumed although this condition is practically harmless. However, a great variety of harmful microorganisms are added from the surrounding air and through knives, equipment and the workers.

In the absence of air, fresh and cured meats present a range of spoilage conditions. They may turn sour because of the production of various acids especially the objectionable butyric acid. In a very advanced stage of spoilage meats undergo putrefaction which is the breakdown of the protein in meat to give foul smelling compounds such as hydrogen sulphide and ammonia, and this bad odour alone would serve as a deterrent in the consumption of such meats. Putrefaction is usually caused by species of *Clostridium* although other bacteria may accelerate the deterioration process. Enzymic activity is also marked in meat and meat products. A beneficial change occurs when slight activity gives rise to tender meats but enhanced activity would result in the decomposition of protein and fat components. Protein is hydrolyzed to the basic unit namely amino acid, but 'souring' and production of toxic amine compounds can also occur. Fats are oxidized becoming rancid with peculiar off-flavours developed in meat. This type of spoilage is also found in cured meats. Gas production may swell packages of sausage when they are packed in gastight, flexible film. Much discomfort can be caused if such spoiled meats are consumed. When a food poisoning outbreak occurs food scientists and microbiologists first investigate the meat that was consumed by the patients as in most cases spoilt meat happens to be the cause.

### **Fish and sea food spoilage**

Fish, both from fresh and sea waters, are consumed after the 'catch' or as dried fish. As in the case of meat, the high protein content of fish makes it vulnerable to both microbial and enzymic decomposition. Since the change is gradual from a fresh condition to staleness and then to inedibility it is difficult to determine or agree on the first appearance of spoilage. However, as the foul odour becomes more pronounced spoilt fish is not usually consumed. The types of microorganisms present in fish are determined by the microbial populations in the waters from which they were caught. The slime that covers the outer surface of fish has been found to be caused by bacteria like *Pseudomonas*, *Achromobacter*, *Micrococcus* and *Bacillus* species. These bacteria are supposed to spread to the interior flesh of the fish through the gills.

Because of the presence of salt the total number of microorganisms is lower in ocean fish where the bacteria found in the skin and slime may be as low as hundred compared to figures as high as several thousands in fresh-water fish.

Fish is more perishable than meat because of greater microbial and enzymic activity. This is attributed to the less acid nature of the fish proteins. Microorganisms similar to those attacking meat invade fish and bring about a succession of external and internal changes as it spoils and finally becomes "putrid". The bright characteristic colours of the fish fade and dirty yellow or brown discolourations appear. Slime, acid formation and the evolution of gases are noticeable signs of fish spoilage. Rancidity takes place as the fish oils are more susceptible to oxidation.

Dried fish and sprats are products of fish processing which are almost staples in our diet. Even though these items are stored in retail markets and in the homes from several months to years, no noticeable spoilage occurs because control is effected by the low moisture and high salt content which is an excellent medium to prevent the growth of microorganisms. Thus dried fish products are safe food commodities having high nutritional value with very little chances of spoilage.

### **Poultry and egg spoilage**

The term poultry is used to describe chicken meat but can also be extended to cover meats of any fowl or bird such as duck, turkey and even game birds.

Essentially poultry is also a meat and thus spoilage characteristics common to meat are applicable to them. The onset of contamination results from the microbial population that live in the intestinal tract with a large addition from feathers and feet. Most of the damage is caused by bacteria although some yeasts too may be responsible for spoilage of poultry. Bacteria (*Pseudomonas*, *Achromobacter*, *Flavobacterium*, *Micrococcus*) and yeasts (*Torulopsis*, *Candida*, *Rhodotorula*) cause sliminess, colour changes and finally putrefaction. These conditions are collectively referred to as 'taints'. Chemical decomposition as in meats may contribute to spoilage by the production of off-flavours and also breakdown of food proteins and other components.

Eggs constitute a fairly cheap source of good protein which is commonly consumed in Sri Lanka. The inside of a freshly laid egg is sterile but becomes contaminated by microorganisms from poultry dung, litter, soil and the hen itself. Molds and bacteria especially

the latter grow through moistened shell into the egg. This microbial invasion takes place more rapidly with defective eggs showing external cracks, leaks, and lack of gloss. Internal defects can be made visible by 'candling' or use of transmitted light. Bacterial damage may cause the egg yolk to disintegrate or blend with the white. This causes a change in the physical condition of the contents which become thinner and more watery as the egg ages. On breaking an egg this condition could be easily seen as the yolk flattens out because of the weakness of the yolk membrane. A number of colour changes are observed which are called "rots". They are caused by bacteria, eg. black (*Proteus* spp), green (*Pseudomonas* spp), pink, red (*Serratia* spp) and colourless (*Achromobacter* spp). Spoilt eggs are readily detected by the foul odour produced by hydrogen sulphide and other gases so that such eggs are not consumed. This is important since off-flavours develop in eggs with little outward evidence of spoilage. Eggs stored for a long period lose moisture and hence reduction in weight is observed.

#### **Milk and milk product spoilage**

In the final group of food products are included fluid milks such as fresh, pasteurized and sterilized milks, sweetened condensed milk, dried milks such as Lakspray and the various milk products namely cheese, butter, curd, yoghurt and the like.

Milk is the secretion of the mammary gland of mammals. Its nutritive value is unparalleled and it has been described as the perfect food. Because of the readily available nutrients associated with the high moisture content, microorganisms can readily grow in it and cause spoilage. Milk leaving the udder of the cow is a sterile product but soon gets contaminated with a whole host of microorganisms from the cow, equipment, air and workers. The effect of these microorganisms could be easily seen when a bottle of fresh milk is kept at room temperature when it is found to curdle in 24 - 36 hours. This condition is known as souring and caused by species of *Lactobacillus*. It is to overcome this type of spoilage that the National Milk Board sells processed fluid milks such as pasteurized and sterilized milks. Pasteurization is the heat treatment applied to milk which destroys all disease causing microorganisms such as *Mycobacterium tuberculosis*, *Staphylococcus typhi*, *Brucella abortus* and *Coxiella burnetti* which cause tuberculosis, typhoid, brucellosis and Q fever respectively. Sterilization kills all categories of microorganisms since the milk is subjected to a very high temperature.

Souring of milk is inevitable if proper storage conditions are not maintained for fresh milk. As the milk undergoes fermentation small particles of curd are seen in a rather watery medium called whey. Fermentation results in the formation of lactic acid accompanied by production of carbon dioxide and water vapour. Sliminess or ropiness is caused by bacteria. All these conditions not only create physical changes but also affect taste and smell to give sour, bitter, burnt and other flavours. As a result of enzymic activity, the usual breakdown of food components takes place.

Processed milks also show different spoilage characteristics due to faulty techniques or unclean conditions. Sweetened condensed milk when packaged in leaky cans are attacked by microorganisms to give rise to thickening or ropiness of the product. Cheese may become moldy (*Mucor* or *Alternaria* spp) or produce off-flavours because of bacterial activity. Spray dried milk like Lakspray is fairly resistant to the growth of microorganisms because of the low moisture content. However, if moisture enters the product bacteria such as *Microbacterium* could grow in it and cause spoilage. Ice cream kept cold does not usually spoil but this too may be invaded by psychrophiles or low temperature loving microorganisms (*Pseudomonas* spp). Butter which contains about 80 per cent fat is free from microbial invasion but rancidity can develop when stored at room temperature for a long period. As a general rule it is best that milk and milk products are stored at low temperature usually in the refrigerator.

## Chapter 4

### HEALTH HAZARDS IN FOODS

Proper utilization of food contributes to physical mental and emotional health. On the contrary as a result of food spoilage brought about by bad handling, unsatisfactory storage, etc. there are ever present hazards to the consumer. A wide range of ill-effects from mild disease conditions to mortality can result because of food poisoning and food infections.

#### Food poisoning

Food poisoning refers to an illness that is caused by toxins in the food. As a rule, the toxins are produced as by-products of microbial growth. Once contaminated, the food can never be guaranteed safe because even if we kill the bacteria by some method of processing there is no guarantee that the toxins produced will be destroyed. There are actually two types of toxins produced by microorganisms. Exotoxins, which diffuse from the microorganisms into the surrounding material, are usually destroyed by heat. Most of the toxins produced are fortunately of this type and are destroyed by cooking. But other toxins are a part of the cell of the microorganisms and are difficult to destroy. Modern food poisoning attacks are commonly associated with three specific bacteria namely (a) *Clotsridium perfringens* (b) *Clostridium botulinum* and (c) *Staphylococcus aureus*.

#### Food infections

Food infections are different from food poisoning in that the microorganisms themselves rather than one of their by-products cause the sickness. These infections are usually of two types. The first is where the food acts only as a carrier for the disease and the microorganisms do not grow until they are inside the body. The other is where the microorganisms grow right in the food and whole colonies of microbia are ingested when food is eaten. Tuberculosis, diphtheria, dysentery, typhoid fever and cholera are diseases spread with food acting only as a carrier. *Salmonella* and *Streptococcus* species are bacteria where the food actually serves as the culture medium.

## Chapter 5

### PRINCIPLES OF FOOD PRESERVATION

From time immemorial, some form of food preservation has been practised in all parts of the world. Although no scientific methods were known at that time, yet mankind found ways and means by which food could be kept a little longer. Cooking of hunted meats over open fires, salting drying, and other operations were used throughout history. These techniques which proved effective at that time are practised even today for food preservation.

The scientific basis of food preservation was first proposed in 1860 by Louis Pasteur who showed that food spoilage was caused by microorganisms. He was able to demonstrate that if food was adequately heated the causative microorganisms were destroyed. In fact the term pasteurization was introduced by him and this type of heat treatment has wide applications in the food industry to prolong the storage life of foods. The ultimate goal of most processing operations or Food Technology is the preservation of food. Knowledge concerning control of spoilage microorganisms and enzymes could be directed towards the development of various processing techniques for the effective preservation of food. If you walk into any retail food store in the country such as the Cooperative Wholesale Establishment (CWE) or Markfed, a number of preserved foods are readily noticed. Further, the range of food items indicates the variety of ways in which food is processed for preservation. Some of these items are jams, cordials, canned fruits, tomato sauce, dried fish, lakspray and condensed milk.

The principle of food preservation could be summarized as the effective control of the causative factors of food spoilage. Thus the preservation of foods involve the prevention or control of microbial decomposition, enzymic activity and damage by insects, animals, mechanical cause, etc. To accomplish this one must draw from one's knowledge of food spoilage and the conditions which eliminate or reduce the activity of microorganisms, enzymes and other contaminants. It is rather fortunate that most of the methods used to control microorganisms are also effective against enzymes or chemical reactions in food. However, in instances where processing (eg. drying) might permit enzyme activity the processing often has to be preceded by action to inactivate enzymes so that accelerated damage to food could be prevented.

## Chapter 6

### METHODS OF FOOD PRESERVATION

In effect, methods of food preservation aim at either (a) destroying or (b) inhibiting the microorganisms and enzymes that cause food spoilage. The former technique involves exposing foods to heat in order to destroy spoilage microorganisms, and the food is protected against subsequent contamination by enclosure in an airtight container. The second procedure aims at subjecting the food to conditions that inhibit or retard spoilage. However, the limitation in this case is that, as total destruction does not take place, foods will undergo spoilage as soon as the inhibitory influence is removed. For example, freezing is an ideal method of food preservation but as the food is brought to room temperature it begins to spoil.

Table VI gives the different methods of food preservation and indicates the principles which underly each method. Of all these methods only sterilization destroys all microorganisms and inactivates enzymes and it is hence one of the best ways of preserving food. The objections to the other methods is that they only inhibit the causative factors by providing unfavourable conditions in the food (removal of moisture, elimination of air etc.) so that the effects of microorganisms and enzymes are only suppressed.

**Table VI Methods of food preservation**

<i>Principle</i>	<i>Method</i>	<i>Preserved foods</i>
Heat treatment	Pasteurization	Milk, wine, beer
	Sterilization	Milk
	Canning	Canned pineapples
Water removal	Concentration	Fruit cordials, condensed milk
	Dehydration	Lakspray
	Freeze drying	Nescafe
Reduced temperature	Cooling	Butter
	Freezing	Frozen foods, ice cream
Activity of beneficial microorganisms— Acidity	Fermentation	Yoghurt, curd, cheese, pickles
Plasmolysis	Addition of salt and sugar	Foods packed in brine or sugar syrup
Lethality of hydrogen ion or undissociated molecule	Chemical additives	Fruit juices, cheese, jams, jellies
Inhibitory or toxic effect of essential oils	Spices and condiments	Cured meats, pickles
Dehydration and germicidal effect of volatile compounds	Smoking	Meat, fish
Oxygen removal and substitution by inert gases	Controlled atmosphere	Avocados, pineapples, frozen fish
Inactivation by electromagnetic rays	Radiation	Spices, flour, fish, meat

## Heat processing

The application of heat to foods technically called "Thermal processing" may take several forms. The most common of course, is the cooking process. Whether cooking is done by boiling, frying, roasting, baking or some variation of these treatments, the process consists essentially of subjecting the food to an elevated temperature. The main purpose of cooking is to make our raw foods more palatable.

In the cooking process we find a very efficient method of food preservation, as many of the microorganisms and enzymes are destroyed by heat. However, the preservative effect is realized only because food is consumed soon after cooking or within a short time. If food is kept for several hours then contamination occurs and it is no longer safe for consumption. Although most homes use the heat processing method of food preservation, yet, care must be taken in eating left-over food which is a fairly common practice in Sri Lanka. In addition, constant heating and cooking of food encourages the rapid growth of microorganisms which can cause food spoilage and present various health hazards to the consumer.

In the food industry either in a large scale commercial operation or in a cottage industry, heat processing of foods is done by pasteurization or sterilization. Solely from a food preservation angle, sterilization is more effective as it kills all microorganisms, while pasteurization destroys only the pathogenic types. However, as the heat treatment is quite severe in sterilization it may also impart undesirable qualities to the food. Therefore most procedures for thermal processing of foods are compromises between obtaining the desired shelf life for the food and at the same time retaining as much of the desirable flavour as possible.

Pasteurization is a heat treatment which is of wide use in the food industry and can be applied to milk, fruit juices, wines, beers, eggs, egg products etc. As the heat treatment given to these foods is fairly mild there are no disagreeable flavour changes or marked differences from the original product.

For proper pasteurization it is necessary that every particle of the food reaches a required temperature and be held at that temperature for a specific period of time. The selection of pasteurization conditions is thus based on the temperature that must be maintained for a sufficient

length of time to destroy pathogenic microorganisms. Usually the required temperature is based on that needed to destroy the most heat-resistant pathogen. In this manner very definite time-temperature relationships have been established and in some countries these are legally enforced so that the consumer obtains a quality product. Minimum pasteurization temperatures and holding times required for selected foods are shown in Table VII. It is observed that the time-temperature relationships vary according to the composition of the food. When the solid content or viscosity of a food increases it is apparent that slower heat transfer will occur through the food. As such, a higher temperature or a longer time is necessary to assure proper pasteurization.

**Table VII** Minimum pasteurization temperatures and holding times required for selected foods

<i>Product</i>	<i>Pasteurization method</i>	<i>Temperature (°C)</i>	<i>Holding time</i>
Milk	LTLT	62.8	30 min
	HTST	71.7	15 sec
Cream	LTLT	65.6	30 min
	HTST	74.4	15 sec
Plain egg yolk	LTLT	60.0	6.2 min
	HTST	61.1	3.5 min
Sugared egg yolk	LTLT	62.2	6.2 min
	HTST	63.3	3.5 min

LTLT is the Low temperature - Long time method  
 HTST is the High temperature - Short time method

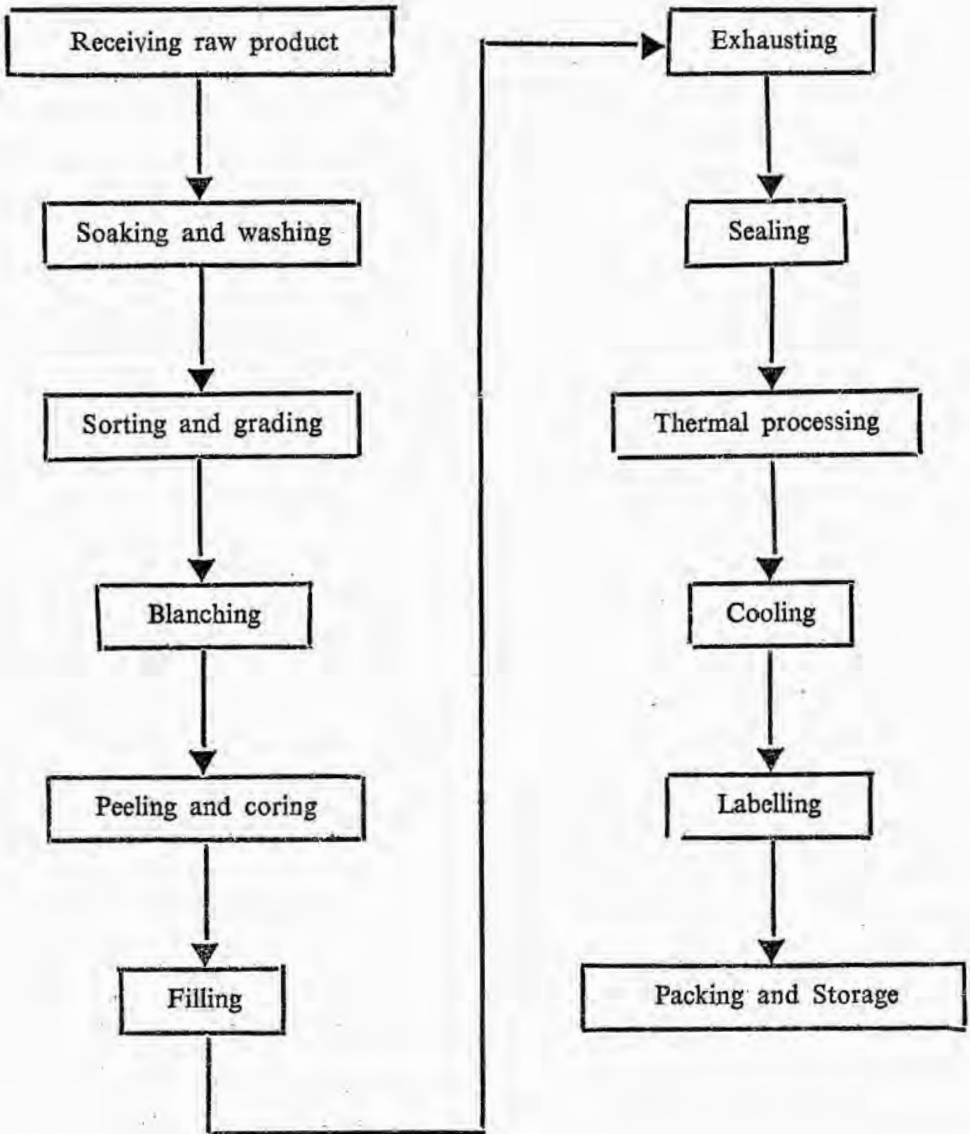
There are two methods used in the food industry for pasteurizing of foods. The older method is to place the food in some type of container or vat and then apply heat either as steam or hot water to the external surface of the container. This is the Batch process where small amounts of food are pasteurized separately and it usually takes a long time. It is thus referred to as the Low Temperature- Long Time (LTLT) process. With advances in food processing operations it was found that the same result could be obtained by a High Temperature - Short Time (HTST) process. This method has the added advantage that the product is in continuous flow during processing, thus making the operation more efficient. For example milk can be pasteurized by the HTST process by holding it at 71.6°C (or 161°F) for 15 seconds or by the LTLT process which involves a temperature 62.8°C (145°F) for 30 minutes. In the National Milk Board or in the Distilleries where wine and beer are manufactured the HTST process is generally used and the pasteurization equipment is designed for speedy operation.

Sterilization implies the total destruction of all microorganisms. This type of heat treatment ensures that foods are completely safe for consumption. However the high temperatures necessary for sterilization cause a number of changes which are often undesirable. Hence for most foods "commercial sterility" wherein all microorganisms that might cause spoilage under normal storage conditions are destroyed is considered sufficient. The amount of heat required to obtain commercial sterility will depend on the type of food being processed. For example high acid foods such as tomatoes and fruit juices do not require a severe heat treatment as low acid foods. The range of sterilized foods marketed in Sri Lanka varies from sterilized milk to canned foods which are all subjected to this type of heat treatment. Canned products such as fruits, are the best examples of food items preserved through commercial sterility.

Canning is really a combination of heat treatment and packaging of the food in an airtight, sealed container. A range of canned products are produced by the Department for the Development of Marketing at its factory situated in Narahenpita. In the manufacture of the final canned product a number of vital steps are necessary. Figure 3 illustrates a flow chart of typical canning operations. As the quality of the final product is dependent on the raw material used it is absolutely essential to standardize the raw material prior to processing. In the canning operation the first application of heat is called blanching. The purpose of blanching is to destroy as many as possible of the microorganisms that are found on the outside of the fruits and vegetables. It also destroys enzymes on the surface which can cause chemical changes in the food during processing and lead to undesirable effects on the texture, structure or colour of the product. Blanching is accomplished in different ways. Sometimes fruits and vegetables are immersed in hot water for a few minutes or passed through a tunnel filled with steam.

The most important stage of sterilization is processing or retorting. The tin cans containing the product with sugar syrup or brine are sealed and placed in a retort which is in reality an autoclave where sterilization is effected. The retort is a large chamber which functions like a metal

**Figure 3** Flow chart of typical canning operations



pressure cooker. It is sealed and steam is introduced. Because the chamber is under pressure, temperatures of 240°F – 245°F can be reached without boiling. The product is held in these retorts for the required length of time. When glass containers are used, lower temperatures and longer time periods are generally applied to avoid the risk of fracture. The pressure is then gradually released and the hot products removed from the retort. This treatment is usually sufficient to render the product commercially sterile.

Canning operations done properly enable food to be stored for a great length of time at room temperature. This is a decided advantage in Sri Lanka where refrigeration and freezing equipment are quite expensive. However, inadequate processing or leaky cans result in spoilage of canned foods. In most instances any incidence of spoilage is noticeable because of a definite indication of swelling of the cans caused by the activity of gas-forming microorganisms or alterations in the canned product.

### **Dehydration**

As the term suggests, dehydration implies the removal of water from food by means of a number of processing techniques. The major constituent of food is water and in some cases such as milk and fruit juices it exceeds 85 per cent of the food. Since a high moisture content is favourable for the growth of microorganisms and for enzymic activity, removal of moisture inhibits both these spoilage factors.

Complete removal of water is not possible as a certain amount remains bound to various food components such as proteins. Further, undesirable changes occur in the food when large amounts of water are removed. Thus a partial removal of moisture is desirable and this process is referred to as concentration. The removal of moisture to five per cent or less is called dehydration. An added advantage of these two methods of food preservation is that they cause a reduction in the bulk or weight of the food which results in reduced costs of packaging and transportation. Imagine the extent of transportation that is necessary if the milk equivalent of a few thousand tins of Lakspray has to be distributed or if fruit cordials are transported as fruit juices. An added benefit is convenience since the consumer merely adds water or 'reconstitutes' and obtains the original product.

Concentration refers to the partial removal of water from a food product. There are many types of concentrated foods available in the market such as evaporated milk, marmite, soups, pastes, purees or products of this type.

Water is removed from a food in different ways but in all instances it is evaporated from the medium. The most common method is atmospheric evaporation. Here the food is placed in an open pan or utensil and heated so that water would boil away at atmospheric pressure. A modification would be to place the food in containers that have large surface areas and expose them to sunlight for the gradual evaporation of water. This procedure has been used for the concentration of brines and sea water in the manufacture of salt. Atmospheric evaporation is the major means of removing moisture in the drying of paddy and other cereals, fruits and nuts. This is very widespread in Sri Lanka and has many applications. A limitation is the slowness of the process, and in the long period of exposure, spoilage can occur if contaminating organisms are present. Further, because of changes that occur in certain foods, atmospheric evaporation cannot be used for concentrating them. The process of vacuum evaporation was developed to reduce the deleterious effect of heat on foods which are concentrated by direct heating. Vacuum evaporation is accomplished by reducing the pressure so that water can be removed from the food by boiling at a low temperature such as 45 -50°C. By this technique it is possible to increase the rate of evaporation and minimize heat damage to food. This method of water removal is done using vacuum evaporators.

Dehydration of foods down to a residual moisture content of less than five per cent is necessary to achieve the maximum benefits of preservation. The resulting food is usually a dry substance which upon the addition of water will resemble, within limits, the original food product.

The oldest method of drying foods is by sun or air drying. It is reported that early human civilizations hung meat in the sun so that, with drying, a fairly safe product was obtained. Maldivian fish, sprats, and other dried products are prepared in this fashion. When we consider dry fish it is seen that an additional food preservative namely salt is added to further extend the storage life of this product.

Sundrying is a very inexpensive form of drying if atmospheric or climatic conditions are favourable. In the alternative, forced air-drying could be done using specially designed equipment where hot air is blown over the food to remove moisture. The best known example of this is the spray-dryer. Lakspray as the name suggests is a spray-dried milk powder. In fact all powdered milks are spray dried. Spray drying is one method that lends itself to convenience and bulk production. In spray drying, a stream of the liquid product which has been reduced to a fine spray or mist is introduced into a drying chamber. As warm air is passed over the product or travels with the product, evaporation takes place until a dried product is obtained. Dried products such as Nescafe are freeze-dried. In this case foods are first frozen and then dried by sublimation where the water is evaporated from the ice without any melting of the ice.

Whatever means is adopted to remove moisture from a food care must be taken that proper storage conditions are maintained to avoid spoilage. Usually dried products are fairly stable but contact with moisture and contamination must be avoided.

### **Refrigeration**

While thermal processing involves the application of heat to foods, refrigeration, either by cooling or freezing is done to reduce the temperature of the food. Low temperatures preserve foods by retarding or preventing the growth of spoilage microorganisms and inhibiting the action of enzymes.

Everyone is aware that fish is transported from the sea or lagoon to the fish market packed in ice. In this way fish can be safe for purchase when there is no excessive time lapse. When ice is placed on a warm food product energy flows from the food to the ice, melting the ice and cooling the food. With the development of mechanical refrigeration it is possible not only to manufacture ice but also to use it directly to chill and freeze foods.

In comparing cooling with freezing, it is obvious that freezing is a more efficient method of food preservation. As the temperature is maintained at 0°C or below, all the moisture present in the food exist as ice and as such it cannot be utilized by microorganisms.

Further the temperature is too low for enzymic activity. Cooling keeps food for a shorter period and the food will eventually spoil because there are microorganisms which can grow and multiply at temperatures just above freezing.

Refrigeration equipment is fairly expensive in our country and as such is not found in the majority of households. However, it is recognized by food scientists that this is one of the best methods of food preservation as it causes the minimum amount of damage to foods compared with other types of food preservation.

In Sri Lanka, refrigeration facilities are available in the larger retail outlets where all categories of perishable food are stocked in freezers. Even the household refrigerator is designed to contain a freezer compartment where the highly degradable products such as meat and fish are stored in a frozen state. The other commodities are generally stored chilled or cooled at a temperature which is slightly above freezing.

### **Fermentation**

The development of fermented foods such as cheese, curd, yoghurt, wines and pickles resulted from more or less accidental discoveries. Man found that some foods as they underwent decomposition during prolonged storage were converted into products that were edible and were in fact more desirable than the original products. Fruit juices are converted to wines and milk to a number of dairy products. These products are obtained through the process of fermentation which is essentially the action of microorganisms on certain foods. Here is an instance where microorganisms are of benefit to man.

Originally, fermentation meant the process of bubbling of gas as observed in the production of wine. Later the term was used to indicate the action of microorganisms on carbohydrates. There are three types of fermentation which result in the formation of useful food products. The first is the action of bacteria on carbohydrates to produce lactic acid and other by-products. It is in this way that various fermented dairy products and pickles are obtained. The lactic acid produced inhibits the growth of spoilage microorganisms. Another type of fermentation is the action of yeasts on sugar substances to give alcoholic products such as toddy and wine. The third type of fermentation is the conversion of alcohol to acetic acid as in vinegar production.

By fermentation, foods that normally spoil are preserved for a longer time and also variety is added to the diet. Consider the possibility of obtaining over 700 different varieties of cheese or a wide range of wines and other alcoholic beverages which are all products of fermentation. Fermentation has an important place in the food habits of people in Sri Lanka and throughout the world.

### **Preservatives**

The more common preservatives added to foods are salt and sugar. Meat products such as salted beef or dry fish are preserved because of their high salt content. Fruits on the other hand are placed in sugar syrups for extended storage.

In addition of salt or sugar for preserving food the identical principle is involved. Microbial cells whether they be bacteria, molds or yeasts are all bounded by cell membranes. These membranes enable water to pass in and out of the microbial cells which contain about 80 per cent water. When a concentrated salt or sugar solution surrounds a microbial cell the process of exosmosis takes place. This means that water moves out of the microbial cell into the exterior concentrated solution. This causes a partial dehydration of the cell, a condition referred to as plasmolysis. By this, microbial growth and multiplication are inhibited and the possibility of spoilage minimized. On the same principle salt and sugar have the capacity to tie up moisture and make it unavailable to the microorganisms. When salting is linked with drying it has an added advantage and this accounts for the fact that dry fish can be kept for a prolonged storage period.

### **Chemical Additives**

It is generally accepted that salt and sugar are natural preservatives. Another means of food preservation is the use of various substances called chemical additives which are capable of delaying or preventing food spoilage. These preservatives may inhibit microorganisms by interfering with their cell membranes, enzymic activity or their genetic mechanisms. They may also serve as stabilizers or antioxidants to prevent physical and chemical changes in the food.

The ideal preservative should be harmless and active when only very small amounts are added to the food. Unfortunately there is no

such ideal preservative and as such great caution should be exercised when chemical preservatives are used. In the food industry, the indiscriminate use of chemical additives is not permitted as excess amounts of some chemicals can be hazardous to the consumer. Hence their use is very closely controlled, sometimes by the use of legal measures.

A wide range of organic and inorganic compounds, chiefly in the form of acids, function as chemical preservatives. The preservative action is brought about by the toxicity of the undissociated molecule in the case of organic acids, and by the hydrogen ion concentration in inorganic acids. As a general rule it is preferable to add organic compounds either as acids, alcohols or antibiotics. Among the organic acids benzoic, acetic, lactic, propionic, citric and sorbic acids find useful applications in the food industry. Benzoic acid is one of the best known preservatives with a general antiseptic effect while compounds like sorbic acid have selective action and are used to prevent mold growth. Most of the better known antibiotics have been tested on raw foods especially the high protein meats, fish and poultry. Although studies show that aureomycin and terramycin are effective as preservatives yet their use should never be a substitute for good hygiene.

The inorganic preservatives are mainly acids and salts. In this category are also included alkali, alkaline salts, metals, halogens, peroxides and gases. In their preservative action acids injure cell membranes and encourage decarboxylation of amino acids in the food proteins. Nitrates, nitrites and hypochlorites of sodium have certain applications as preservatives. Sulphurous acid or sulphur dioxide gas inhibits the growth of molds while helping to retain the colour of foods. Nitrates and nitrites are used for curing of meats in addition to their role as food preservatives.

### **Spices and condiments**

The diet of the indigenous population like that of most Asians is generally highly spiced. We use generous amounts of chillies, pepper, cinnamon, garlic and other spices and condiments especially to add flavour to food. Although in the concentrations used, spices are not sufficient to act alone as preservatives, it is found that they add to the effect of preservatives.

In all cases the inhibitory or toxic effect of spices and herbs is due to the essential oils they contain and this effect is sometimes said to be even greater than that of chemical preservatives. Among the spices it has been established that mustard, cloves and cinnamon have the greatest preservative action. The results of a number of tests using different bacterial species clearly demonstrate that there is considerable variation in the resistance of specific microorganisms to the same spice. However, most spice oils are germicidal being able to destroy most types of microorganisms. Some of the active principles found in spice oils are the chemicals eucalyptol, allyl isothiocyanate, carvacrol, cinnamic aldehyde, cinnamyl acetate and eugenol methyl ether.

### **Smoking**

In many homes especially in the rural sector of Sri Lanka foods are placed over the fire-place with the aim of preventing spoilage. The use of woodsmoke, besides serving as a preservative, also adds desirable flavours to the food. Woodsmoke has another beneficial effect, namely improving colour and tenderizing meats.

Smoke is produced by the burning of wood and in the initial stage the heat produced has a germicidal and dehydration action on the food. Additional inhibitory effects on the growth of microorganisms especially bacteria are brought about by the large number of volatile compounds in the smoke which include formaldehyde, phenols, cresols, aliphatic acids, alcohols, ketones, aldehydes and a host of other compounds. In addition to the bacteriostatic action, these volatile compounds tend to coat the food thus preventing secondary infection by microorganisms and giving a desirable flavour to the food.

### **Storage in a Controlled Atmosphere**

Agricultural produce continues metabolic activities for a certain period of time after harvesting. This results in damage to food because of the oxidative and respiratory processes that occur in the tissue. Most of these activities are accelerated by the presence of oxygen and thus storing foods in an inert atmosphere would eliminate or reduce undesirable changes. Another consideration is the fact that many microorganisms require oxygen for their growth and multiplication. Hence definite advantages could be realized by replacing oxygen with an inert gas as the medium surrounding the food.

In storage in a controlled atmosphere the oxygen in the immediate environment of the food is replaced with nitrogen, sulphur dioxide, ozone, carbon dioxide or nitrogen trichloride. The respiration and ripening of fruits can be retarded by controlling the carbon dioxide and oxygen concentrations of the atmosphere. Premium priced fruits like avocados can be exported by packing in an inert atmosphere thereby delaying the ripening process. This reduces decay since overripe fruits are more liable to microbial spoilage. Storage in a controlled atmosphere could also be combined with low temperature and meats, eggs, fish and vegetables are sometimes frozen in packs containing inert gases. Vacuum packaging, waxing and wrapping food in oxygen impermeable polythene materials achieve the same objective by either removing oxygen or preventing its entry. Whichever method is adopted it should be noted that the storage characteristics of a food is largely determined by the initial infection of microorganisms. The major limitation of storage in a controlled atmosphere is that microorganisms capable of growing without oxygen, namely the anaerobes, are not inhibited by this method.

### **Radiation processing**

The use of radiations in most aspects of science has gained prominence in Sri Lanka in the recent past with the institution of the Atomic Energy Authority. In the area of food preservation X-rays, microwaves, ultra-violet radiation and ionizing radiations of different wave length have been used to extend the storage life of foods.

Radiation has a lethal effect on microorganisms. Microorganisms in food are inactivated to varying degrees by different kinds of radiations. Ultra-violet rays have a very low penetrating power so that the inhibitory effects are confined to organisms that invade the surface of food. It has been established that the wavelength for maximum germicidal effect is 2,600 Å. Low pressure mercury lamps have a high output at 2,537 Å which is close to the peak bacteriocidal wavelength. In the context of the present day usage, radiation treatment is usually meant to imply that the food is irradiated with ionizing radiations from radioactive isotopes or electron accelerators. Although the use of irradiation to improve the keeping qualities of food would play an important role in international trade in food, it must be stressed that it should not entirely replace other preservation methods.

## Chapter 7

### CONCLUSION

Every endeavour should be made to utilize fully the foods that are available in this country. To feed adequately the indigeneous population, various food production efforts have been sponsored throughout Sri Lanka. Schemes like the Mahaveli Development Project would certainly go a long way towards ensuring that the population receives sufficient quantities of food. However, in all these ventures, wastage must be eliminated or reduced to achieve the desired results. In this regard, food spoilage is an important problem to contend with, since the tendency to spoilage is high in the climatic conditions experienced in Sri Lanka.

Knowledge of the causative factors of food spoilage is an indispensable pre-requisite for appreciating fully the vulnerable nature of food to the attack of microorganisms and enzymes. Bacteria, molds and yeasts are of universal occurrence, and they can readily invade food. Enzymes are vital components of plant and animal tissue. Hence the causative factors are ever present and food spoilage is inevitable unless proper preventive measures are taken effectively to control food spoilage. If spoilage goes unchecked it must be realized that the food losses that occur are not only quantitative but also qualitative wherein valuable nutrients are destroyed.

Although various food preservation techniques are available, yet, none of them could replace good hygiene and sanitation which must be strictly enforced in all aspects of handling and processing of food. To obtain maximum benefits it is generally recognized that a combination of some of the techniques described should be used and that reliance should not be placed on one particular method of food preservation. The methods selected, however, should be considered in relation to the available facilities, finances, and other factors. Adoption of suitable techniques would ensure food preservation so that with the elimination of losses everyone will be able to relish with delight the wholesome food that is produced in Sri Lanka.

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