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KNOWLEDGE IS OF TWO KINDS:
WE KNOW A SUBJECT OURSELVES
OR WE KNOW WHERE WE CAN FIND
INFORMATION UPON IT

PREFACE TO THE GOLDEN JUBILEE EDITION

In 1961 Food Technology discipline emerged as a major subject in the then West Pakistan Agricultural University Lyallpur for the first time in Pakistan. The author was among the first 20 students to be selected for this major discipline. At that time no one was acquainted with this subject. The times have changed. Now Food Technology is being offered in several universities and colleges of technologies throughout the Country. This book adequately meets the requirements of HEC Curriculum for B.Sc. Hons. Food Science and Technology 2010 for the course titled "Food Processing and Preservation". It also embraces the needs of the students enrolled for DAE in various colleges of technologies.

The University of Agriculture Faisalabad has decided to celebrate the year 2011 as its Golden Jubilee year and has chalked out numerous academic events in this regard. This Golden Jubilee edition of the "Food Processing and Preservation" is a humble contribution in these celebrations. In this edition (3rd) minor changes have been made wherever necessary. It is hoped that this book, in addition to be useful to the students, will also help refresh the knowledge of food technologists working in the food industry and improve their job skills.

Dr. Javaid Aziz Awan
March 2011

Saleem

Saleem

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REVOLUTIONS IN FOOD SECURITY

Food is one of the basic necessity of mankind and all living organisms. In the earlier days of human history, man was a hunter and a gatherer. If he was able to hunt an animal or collect some food from the fields, he had the food security for a day or two. Gradually he realized that gathering and hunting would not suffice, hence he resorted to domestication of a selected number of plants and animals for food. In this process, species with great native variability were introduced. The types that performed best in each area were perpetuated thus giving rise to distinct varieties and species. This has resulted in good harvests at times. However, owing to environmental and political circumstances, generally the situation has been that of a shortage (drought, flood, war, poverty). As a result, mankind has suffered from famine and inadequate supply of food.

Food security is a situation "when all people, at all time, have physical and economic access to sufficient, safe, and nutritious food, and to meet their dietary needs and food preference for an active and healthy life". The three dimensions in this definition are:-

a. Adequacy of food (effective supply)

b. Ample access to food (the ability of the individual to acquire sufficient food or effective demand), and

c. Reliability of both supply and access (equity of food distribution)

The last century witnessed three major revolutions in agricultural technology that have provided mankind with sufficient food. The first revolution was based on mechanization. This is very productive in terms of output per man-year. It has resulted in increase in cultivable land, intensive farming and greater crop yields. The second revolution was founded on the science of chemistry. It enabled the development and production of fertilizers, pesticides and other agricultural chemicals. This has further helped to enhance the crop yields by providing the required nutrients and preventing the activities of pests.

The last revolution is based on biology, the green revolution. The introduction of semi-dwarf, high-yielding fertilizer-responsive and disease resistant wheat varieties contributed larger harvests from a given area of farmland. The foundations of this revolution are based on improved breeding techniques, applications of the science of genetics, genetic engineering and biotechnology. This has provided mankind with crops that are high yielding and resistant to adverse ecological circumstances such as pests, drought and others. The plant breeders have sought out crop varieties with characteristics that might help the poor farmers in developing countries grow more food. The high yielding varieties of wheat, rice and other food staples have helped avert catastrophic famine in Asia in the 1960s and 1970s. Their work continues to improve the lives and livelihoods of millions of people on the planet Earth. It must be remembered that the physical resources of the food system, that is, land, air and water are essentially fixed. So is the energy input required to exploit these means. The biological and social inputs, however, are far more from being pressed to the limit.

The rapidly growing world population requires new agricultural technologies to boost food production. Only with higher, sustainable yields can more people be fed without harming the environment. The farmers need to use the most appropriate means possible to effectively manage natural resources and feed the world's growing population. Agricultural biotechnology is just one of many essential tools to achieve the goal. This tool can be brought fully to bear on developing more productive and nutritious crops. However, it raises several complicated issues for the developing countries. The intellectual property rights are likely to affect agricultural biotechnology. The private corporations in the developed countries are taking out patents and other forms of protection for their new genetically modified (GM) crops and for related genetic materials. In this manner the developing countries are being deprived of the benefits of the biotechnology revolution.

Poor nutrition is a violation of an individual's human rights, and it causes untold sufferings. Good nutrition depends on proper access to food, care, and health and sanitation services. Improvement in nutritional status is now being used to judge the success of a wide range of development strategies. Millions of people in developing countries suffer from a lack of calories, proteins, micronutrients (vitamins and minerals) and from illness and impaired physical and mental developments. In these regions, staple foods make up a large percentage of the diet and the majority of foods are not processed. In the developed world, people have easy access to healthcare, fortified foods and vitamin supplements. In these countries a worthwhile approach is to process the foods that people already eat and make them more nutritious.

The revolutions in agricultural technology have not only kept pace with the population growth, but have surpassed the food needs of the people. These revolutions in agriculture have definitely helped to boost agricultural production and provide more and nourishing food for the rising population. The situation that prevails now in the world is that there is plenty of food for everyone on this globe provided the food is equally distributed. For this purpose there is a need to find techniques and methods that would permit safe delivery of sound, nutritious and wholesome food. All revolutions and all efforts to increase the food production would be futile without saving the food from wastage—that amounts to over 40% in fruits and vegetables and 20% or more in cereals and legumes in most developing countries. The prevention of food losses from spoilage is critically important.

In the 1860s, Louis Pasteur discovered that microorganisms were the cause of disease and decay. This immensely important discovery—the discovery of the principles of food preservation, has led to yet another revolution. This is a revolution that has helped to supply food to non-food producing areas, to areas of famine, to places where people relish such foods and to places where food is needed. This is a revolution that has led to scientific expeditions to the highest mountains and deepest seas on the earth, and ice laden North and South Poles. This discovery has enabled man to travel to the space and set its foot on other planets.

This revolutionary discovery has helped mankind to prevent starvation during periods of low harvest. If this revolution is fully utilized, then there would be no hungry soul on this earth. Presently, there is a need to improve the storage of already existing food instead of producing more food. This food has to be distributed in a fair way. People still die of hunger just because we do not find model which enables us to distribute food with more justice.

In the early days, this discovery was applied to milk and wine. Later it was extended to other foods by Nicolas Appert, the father of canning. Now this revolutionary discovery is being applied to almost all foods in one form or another. The scope of this discovery has extended from the use of high temperature (as in pasteurization and canning) to the applications of low temperature (in cold storage, refrigerated storage, freezing), to removal of moisture (drying, dehydration, evaporation, binding of moisture). Furthermore, numerous chemicals have been discovered that prevent the growth and activities of microorganisms (preservatives). In addition, microorganisms themselves have been harnessed and exploited to preserve and produce new foods (fermentations). The investigations on the electromagnetic spectrum have led to the discovery of electromagnetic waves that are useful in extending the shelf life of foods (use of radiations). Packaging has also emerged as a technique to supplement the action of preservative agents.

This is precisely what food technologists are trained to do. Their efforts are geared towards preservation of foods so that these can be distributed over long periods and distances. To reap the benefits of this ultimate revolution in food security, food technologists the world over are making efforts to utilize the food produced and provide the consumer with nourishing, wholesome and safe foods.

"ALL WISH TO POSSESS KNOWLEDGE, BUT FEW, COMPARATIVELY SPEAKING, ARE WILLING TO PAY THE PRICE"

2

PRINCIPLES OF FOOD PRESERVATION

The activities of spoilage agents are dependent upon several factors and that a change in any of these results in their decreased performance. The principles of food preservation are based precisely on this knowledge and on the understanding of how chemical reactions, physical changes and pest attack collectively reduce the quality of foods. These principles may be stated as follows: -

Principle 1

Autolysis in food may be prevented or delayed by the destruction or inactivation of enzymes and by the treatment and handling of food in such a manner so as to inhibit the reactivity of chemically active molecules.

Principle 2

Spoilage in foods as a result of microbial activity may be prevented or delayed by either prohibiting the entry of microorganisms into the food, physically removing them from the food, hindering their growth and activity or even destroying them, if they are already present in the food.

Principle 3

Quality defects and losses in food caused by insects, rodents and birds may be controlled by adequate packaging and by instituting a sustained population control programme of such pests.

Principle 4

The deterioration in food caused by the physical phenomenon occurring during processing, handling and storage may be reduced by the development of optimal handling, processing and storage conditions.

2.1 PREVENTION OR DELAY OF AUTOLYSIS

Enzymes require specific pH range to catalyze the life reactions. The enzymes are very sensitive to changes in pH of the environment. This information is utilized to preserve several foods by merely altering their pH. For example, in biological preservation of vegetables (pickling), pH of raw materials is reduced through the activities of lactic acid bacteria that produce lactic acid. Some meat and milk products are likewise preserved or produced as a result of change in the pH. Sometimes preformed organic acids, such as acetic acid (vinegar), are added to foods for the purpose.

Enzymes thrive best in a particular temperature range. Any deviation from this to the higher or lower side has an adverse effect on enzyme activity. The food can be subjected to a particular high temperature that will either destroy or inactivate the enzymes. In the food industry, some fruits and most vegetables are normally subjected to around 100°C for a few seconds to few minutes in an operation called blanching or scalding. As a result of this exposure, some damaging enzymes, e.g., the catalase system, are destroyed. Blanching is usually a pre-treatment in several food preservation methods such as canning, dehydration and freezing.

Another procedure employed to delay autolysis is the use of low temperature. The enzyme reactions are retarded at low temperatures that prevail in the refrigerator or cold storages. Thus, refrigeration delays ripening process in fruits. Freezing inactivates the enzymes and sometimes destroys them; hence frozen foods have a much longer shelf life than the fresh ones or those kept at above 0°C.

Enzymes require moisture for the biochemical reactions which they catalyse in foodstuffs. Absence of water would mean that these reactions cannot take place in the medium. This property of enzymes is utilized, partly, in the preservation of foods by removal or binding of moisture. The moisture in foods is removed by sun drying, dehydration, concentration and evaporation. Available moisture may also be bound by the use of chemicals as seen in the production of intermediate moisture foods.

Chemically induced autolysis can be minimized by applying good manufacturing practices (GMP) based on experience and scientific knowledge. Most chemical reactions are retarded by maintaining a low temperature profile, by the use of chemical inhibitors and by proper packaging. Non-enzymatic changes in foods may be prevented by the use of some chemicals, e.g. sulphites to inhibit colour changes or antioxidants to check rancidity. Further control can be achieved by employing low temperature, controlling water activity in dehydrated foods, reduction of reducing sugars in potatoes by storage, reduction of amino-nitrogen content in juices by ion exchange and by packaging with oxygen scavengers.

2.2 PREVENTION OR DELAY OF MICROBIAL ACTIVITY

While enzymes are part and parcel of fresh foods, microorganisms are invaders and where undesirable, they should be treated like any other invader. Firstly, precautions may be taken to prevent their entry into the food, but where they have already gained access, these may be thrown out. When such a strategy is not feasible, the microbial activities may be controlled by creating conditions that do not favour their normal existence. As a final resort, they may be destroyed by any suitable means.

2.2.1 Keeping Microorganisms Out

Nature creates all foods free from microorganisms and provides a protective covering to prevent their entry inside the tissues. Orange, banana, mango, wheat, maize, rice and groundnuts are all free from microorganisms when produced. The skin, peel, husk and shell provide these commodities protection against infection from external sources. Similarly, tissues of healthy animals are free from microorganisms. The skin and fatty tissues give the animal protection from invading microorganisms. As soon as the outer covering of plant materials or animals is injured, microorganisms invade the tissues and start growing, thus causing infection or spoilage. To guard against the entry of microorganisms from an outside source, protective covering is provided for the food in the industry. While fruits, vegetables, meat and other foods may be packed and protected in tin cans or glass containers, some foods are given a coating of wax or other inert material to protect them from the attack of microorganisms. Examples are coating of some cheese varieties and eggs with wax or similar substances.

2.2.2 Removal of Microorganisms

During food processing, it is difficult to keep microorganisms away since these are omnipresent. Even without obvious signs of microbial attack, microorganisms gain entry into food during harvesting, storage and subsequent processing operations. Since microorganisms are very small, it is not easy to pick and throw them out. Fruits and vegetables carry microflora on their surface or in their bruised, damaged and decaying tissues. The food processor washes the raw material thoroughly so that much of the contaminants, including microorganisms, are removed from the surface. The bruised, damaged and decayed portions are trimmed off in the operation designated as trimming. These operations help to reduce the microbial load in the food product and aid in its preservation. However, from liquid foods such as clear beverages (water, fruit juices, wines and beer), microorganisms can be removed with the help of filters—a technique called filtration. In the brewing industry special centrifuges are used to separate yeast from beer. In the dairy industry, centrifugation is applied to separate cream from milk. During this process quite a number of microorganisms are also separated from the milk fraction and are removed with the cream.

2.2.3 Creation of Unfavourable Conditions

Most food spoilage and pathogenic microorganisms are aerobic in nature. The spores of some of these organisms must have oxygen to germinate. This information provides the food technologist with yet another tool to control their activities. Creation of anaerobic atmosphere will prevent growth of vegetative cells and germination of spores. This is usually accomplished in canning by the use of mechanical vacuuming or in an operation called exhausting. The air from the product is removed and the can sealed airtight. Thus, even if these microorganisms have gained entry, under the prevailing anaerobic conditions, they will not grow; hence will not be able to spoil the food. However anaerobic organisms may pose a problem in such processes if their activities are not checked or these are not subsequently destroyed.

Another technique used to create unfavourable conditions and prevent the activities of microorganisms in foods, even after they have

gained entry, is the removal or binding of moisture. All microorganisms require available moisture for their activity. Consequently, if this is less than their requirements, the growth is inhibited. This fact is utilized in preserving foods by removal or binding of moisture. The available moisture from foods may be removed by drying, dehydration, or concentration or is made unavailable by the use of certain chemicals such as sugar, glycerin and other water-binding substances generally known as humectants. In this manner the available moisture in food is either removed from it or made unavailable. The microorganisms thus are unable to grow in their changed environment and the food does not deteriorate or spoil as a result of microbial activity.

In order to prevent growth and activity of microorganisms in foods, some chemical substances known as preservatives are also employed. The use of sulphur dioxide and benzoic acid (added in the form of potassium metabisulphite and sodium benzoate, respectively) protect fruit juices from spoilage in sealed containers. While some chemicals may be intentionally added, others are developed or produced in the food. Lactic acid is a good example of such a chemical. This organic acid is produced by the normal growth of lactic acid bacteria. Thus, in the dairy and meat industries some products are produced and preserved as a result of the activities of certain lactic acid bacteria. Sour cream, butter, cheeses and sausages are representative examples depicting the beneficial activities of lactic acid bacteria. In certain vegetable products like pickles, the activities of lactic acid bacteria are also encouraged. These grow in the juice of the vegetable and produce lactic acid. In this process, pH of the vegetable material is reduced to a point that microorganisms, which normally would grow in or on the vegetable material, are unable to do so.

Temperature is yet another very effective tool in the hands of people engaged in food preservation to create unfavourable conditions. Use of low temperature (chilling or freezing) inhibits the growth of microorganisms—their activities are slowed down at chilling and completely stopped at freezing temperature. Holding foods at freezing temperature or in frozen state also helps to destroy or kill some microorganisms.

2.2.4 Destruction of Microorganisms

Spoilage in foods may also be prevented by destroying microorganisms. High temperatures (above the maximum growth temperature) have adverse effects on microorganisms. Blanching is employed in the food industry primarily to destroy or inactivate enzymes.

However, it also helps to kill some vegetative forms of microorganisms. Pasteurization temperatures (65°C to 88°C) are employed to kill pathogenic organisms including bacteria and yeasts in some liquid foods. Sterilization employs much higher temperatures (100°C or above) to destroy all microbial forms. In food processing, it is neither possible nor practicable to destroy all forms of microbial life (sterilization), hence commercial sterilization or heat processing is employed. Some microorganisms or their spores remain viable after this heat treatment. However, with the combination of other techniques employed in the preservation method, these remain dormant and are unable to cause trouble. The heat treatment necessary to kill microorganisms or their spores will vary from organism to organism, its state (vegetative or spore) and the environment. Depending on the effectiveness of the heat treatment employed, only part of the vegetative cells, or all or most of the cells may be destroyed. Some bacterial spores are also killed at higher temperatures. The heat treatment applied is a temperature/ time dependent phenomenon.

Some chemicals are also very effective in controlling microbial activity in foods. Use of sulphur dioxide and benzoic acid is common in fruit and vegetable preservation industry. In baking, where mould growth is feared, propionates are employed.

Microorganisms in foods can also be destroyed by the use of radiations of various frequencies. The ultraviolet waves from the electromagnetic spectrum have germicidal properties. Gamma rays, emitted from by-products of atomic fission are also germicidal and when applied to food, help preserve them.

2.3 CONTROL OF PEST ACTIVITIES

Insects, rodents and birds have attained pest status in most countries. However, only those are so designated that exhibit prolific reproductive capabilities and compete, often menacingly, with humans for food and space and may be associated with transfer of diseases to man. These are a constant threat to man's survival. The seemingly harmless species are, in fact, a necessary part of the balanced ecological system in which we live.

2.3.1 Insects

Insects alone account for the destruction and waste of almost fifty percent of the annual cereal grain crops in some developing countries. These small enemies of man attack food in the field, processing plants, warehouses, supermarkets, as well as in the home.

Insects do not only eat sizeable quantities of man's food but also damage even greater amounts and create easy entry points for microorganisms. Traditionally, food industry has controlled insect pests in grains and other dried foods by fumigation with such chemicals as methyl bromide, ethylene oxide and phostoxin. These foods are protected from further infestation when treated and packed in insect-proof containers. Insect-proof packaging may not be feasible for all dried foods, especially in developing countries for both economic and logistic reasons. Hence, use of integrated systematic insect control programmes are recommended in the agriculture and food sectors that include both preventive and curative measures.

A typical preventive measure for insect control includes treatment with long-acting insecticides and insect repellants to dress seeds and the use of insect predators or other biological means. Curative insect control programme, on the other hand, involves the use of physical, chemical or biological methods to exterminate insects and insect eggs from already infested food. A popular physical method for destroying insect eggs in wheat flour and other similar size-reduced dry foods involves the use of impact-based instrument, the entolater. Insect eggs that are thrown to the metal body of this revolving instrument are instantly destroyed by impact. Heat disinfection is another physical method employed to destroy insects in stored products. In this case, the temperature of food is raised to about 50°C since insects cannot survive such high temperature. Infrared devices are popular heat sources for heat disinfection of grains on account of their effectiveness and relative low cost.

The most desirable control measures are those that demonstrate effective insect control over long periods without creating intractable adverse effects on man and the environment. Experiences with the control of insects as with other animal pests, have shown that control measures which momentarily and indiscriminately reduce insect populations may introduce serious health hazards and environmental problems in the long run.

2.3.2 Rodents

Gross rodent infestation is readily discovered by the presence of burrows, dark oil and dirty stains on rodent runaways, odour of mice, filth deposited on food, as well as damaged food and other materials. Dry urine appears as darkened stain on food and containers. These stains will fluoresce under ultraviolet light. The presence of rodent filth in food processing and storage premises calls for prompt control measure.

Complete eradication of rodents has, however, proved an almost impossible task. The situation is worse in developing countries where rodent populations are known to overwhelm available control facilities due to poor environmental sanitation. Systematic control of mice and rats is practiced with a reasonable degree of success in most industrialized countries. A typical systematic control includes the use of poison baits, rat-traps and biological methods to kill mice and rats. Rodent harbourages are usually either destroyed or sealed off after treatment with a long-acting rodenticide. Foods are packaged and stored in environments that make rodent invasion difficult. A sustained control effort can yield positive results only if backed by a reasonable measure of sanitation around food handling and storage sites.

2.3.3 Birds

Birds consume substantial quantities of grains in the field prior to harvest. In some tropical countries, birds, such as the weaverbird, have been known to devastate entire corn crop in the field. This loss by bird invasion has traditionally been checked by installing noise-making dummies (shaped like humans or animals) at strategic points on the farm to scare birds away. Apart from the consumption of grains, birds can contaminate food and water. To prevent this, bird screens can be erected over important water supply sources and food handling areas.

2.4 REDUCTION IN PHYSICAL DEFECTS

Added to the defects caused by autolysis, microorganisms and biological pests, additional quality deterioration in food can be caused by physical and physico-chemical interactions. These interactions are induced by series of treatments that accompany food manufacture, handling and storage. There is no simple rule of thumb that predicts the best processing conditions for all types of foods. However, experimentation, experience and current exchange of scientific and technical information on the effects of various processing variables on food quality have helped in the development of optimized processes aimed at keeping physical defects in foods to minimum.

2.4.1 Surface Drying

The desiccation or drying out observed on the surface of certain foods during frozen storage is an important physical defect that can be controlled by adequate packaging and the maintenance of a steady storage temperature. In refrigerated storage of flesh foods, moisture loss and surface drying can be minimized by maintaining higher than conventional average relative humidity in the storage chamber. The

increase in microbial activity induced by such high relative humidity is kept under check by the use of ultraviolet lamp as storage atmosphere sterilants.

2.4.2 Crystallization

Another common physical defect involves crystallization of sugar from syrups and other sugar-based products. Such defective products develop a distasteful sandy texture. Unwanted sugar crystallization in foods can be prevented by using a mixture instead of single sugar. A solution containing above 60 percent sucrose at ambient temperature will develop crystals, whereas a solution containing 75 percent total sugars made up of a careful blend of sucrose, glucose and fructose will show no visible signs of crystals. This knowledge is applied in the production of high sugar products like jams and sugar-based jellies.

2.4.3 Other Defects

Attempts at reducing physical and textural defects in foods during processing and storage are seen in process handling and storage controls applied by the industry. The relative humidity and drying rates are controlled in dehydrators to minimize the incidence of case-hardening; stabilizers are used to prevent the collapse of emulsions during handing and storage. Freeze-drying removes moisture from heat-sensitive foods and enhances the retention of natural nutritional and textural properties on rehydration.

NOTES

"I KEEP SIX HONEST SERVING MEN
THEY TAUGHT ME ALL I KNEW
THEIR NAMES ARE WHAT AND WHY AND
WHEN AND HOW AND WHERE AND WHO"

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3

PREPARATORY OPERATIONS IN FOOD PROCESSING

In the food industry several conscious operations are performed to meet the consumer requirements. These are aimed at ensuring that the raw material is of the desired quality and free from unwanted constituents. These operations are collectively called preparatory operations and include: -

1. Handling and transportation of raw materials
2. Cleaning
3. Sorting and grading
4. Peeling
5. Removal of inedible constituents
6. Size reduction
7. Mixing
8. Filtration
9. Prevention of enzymatic browning

3.1 HANDLING AND TRANSPORTATION OF RAW MATERIALS

Under no circumstance can inferior raw material yield a good quality end product. Proper handling and transportation of raw materials is, therefore, essential to produce good quality end products. Moreover, if the raw material is contaminated before being processed or preserved, greater efforts will be required in later stages to salvage its positive quality potentials. For that reason, as soon as the raw material is harvested, animal slaughtered, or fish is caught, it has to be given adequate treatment. Proper containerization is essential for these raw materials. Suitable containers must be free from contaminants such as fertilizer residues, chemicals, soil, etc. Quite often second-hand sacks are used for packaging or transporting grains. These may have been used for animal feed, fertilizer, cement or other similar products. The raw material gets contaminated in such bags.

Any aspect of the container construction that predisposes food raw material to injury must be avoided, since this will pave way for contamination and growth of microorganisms resulting in accelerated spoilage. The size and type of container is also important. Some raw materials such as tomatoes cannot be packed in deep containers, while onions or potatoes, that are texturally hard, may be transported in bags. In the Pakistani markets, fruits and vegetables to the tune of 40% are lost as a result of improper containerization and handling.

Meat carcasses are usually hung in special transporting vehicles that are equipped with refrigeration system. In Pakistan and other developing countries, meat is transported from the slaughterhouses to the market in all sorts of available vehicles including bicycle, animal driven carts (donkey cart, *tonga*, etc.), rickshaw and others. By the time it reaches the sale point, it gets heavily contaminated.

Fish has to be brought to the market soon after catching as it deteriorates rapidly after death. In most parts of Pakistan it is transported in baskets packed with ice. Eggs have special trays in which these can be placed and the trays are stacked one over another for safe transportation.

3.2 CLEANING

Food raw materials carry several contaminants on their surface. Microorganisms are invariably present in all foods. Carrots, potatoes and other crops that grow beneath the soil surface possess larger and diversified microflora than oranges, bananas or tomatoes. The raw material also gets contaminated with soil, sand and stones from the field. The grains carry foliage, twigs, stalks and other plant materials extraneous to them. Pieces of metals, lubricating oil, grease, and pieces of ropes, strings, etc., may also be present in one food material or another. In addition, pesticide residues and residues from fertilizers applied to crops also form part of the contaminants.

The cleaning operation separates contaminants from the food material and disposes off the same. Once the food surface has been reasonably cleaned, effort is made to limit recontamination and to leave the cleaned surface in the desired condition. It has been observed that vegetable retailers in Pakistan wash their produce in canal or stagnant water. Such a practice adds fine soil particles to the vegetables and leaves the surface contaminated, thus providing a reverse effect.

There are primarily two methods of cleaning, depending upon the raw materials and contaminants: dry and wet cleaning.

3.2.1 Dry Cleaning

This is especially suitable for grains and other crops that are dry and would introduce technical problems if soaked in water. Particles of different sizes are separated by screening—a technique applied in the home for separating coarse particles from flour. If the contaminant and food raw material are of different densities, then aspiration is a suitable method.

Winnowing, finds application in the separation of wheat from straw, rice from husks, groundnut skins from roasted shelled groundnuts and bran from endosperm in flour milling. As practiced at home, food to be cleaned is placed in a shallow wide-mouthed tray or basket and the contents propelled some 10-12 cm upwards into the air. The lighter particles are blown off by wind or air current. This action repeated several times brings about complete separation. Industrially, the process of winnowing is mechanized. Fig. 3.1 illustrates a combined pneumatic and screen separator for grain cleaning in the industry.

Electronic metal detectors are employed to separate metallic contaminants such as nuts, bolts, pieces of broken equipment parts, etc. These remove both ferrous and non-ferrous particles. Strong magnets are employed to eliminate nails, screws, pieces of wires and other ferrous contaminants from the grains.

Other techniques used in dry cleaning of food commodities employ the principle of abrasion and brushing. These techniques are especially useful for heavily contaminated foods such as potatoes, carrots, radish, turnips, and other roots and tubers that grow beneath the soil surface. Special brushes loosen and sometimes remove the adhering soil on these commodities in conjunction with other methods of cleaning.

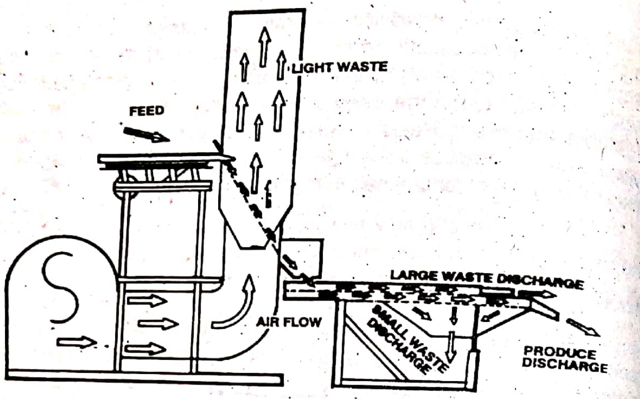

Fig. 3.1 Principles of operation of a combined pneumatic and screen separator

Courtesy: Mather & Platt, Manchester, UK

3.2.2 Wet Cleaning

In wet cleaning, water, which is an efficient and cheap liquid/solvent, is exclusively used for the purpose. The water for cleaning must itself be of appropriate standards, i.e., it should be clean and free from pathogenic microorganisms and toxic substances. It should not contain dissolved solids and should be soft. Proper arrangements for disposal of wastewater are a pre-requisite in the food industry.

Heavily contaminated raw materials such as potatoes and carrots are soaked for some time to loosen the adhering soil before applying any other technique for complete removal of the contaminants. The soaking process is made more efficient if the product is moved in water or the water is agitated. Use of ultrasonic waves above 16 kHz (20 to 100 kHz) for cleaning some raw materials has gained popularity in the food industry. When these waves are passed through the cleaning fluid, violent agitation of particles occurs. This results in loosening of contaminants from the surface of raw material. Spraying may be employed separately or in conjunction with soaking for washing fruits and vegetables. The efficiency of the spraying process depends upon the water pressure and its volume.

Flotation and sedimentation are used when density or buoyancy of the contaminant is different from that of the raw material. The principle

is similar to aspiration but in this case water is the medium rather than air. In cleaning of rice and pulses (*daals*) destined for cooking, the grains are soaked in water; all light particles float and are removed from the surface. The heavier contaminants such as stones settle at the bottom and are removed. Raw peas contain stones along with pieces of leaves, pods and stalks. In a stream of water, stones sink to the bottom and pieces of leaves and stems float to the surface, leaving a layer of "clean" peas in the middle. Contaminants from fresh milk, fruit juices and syrups are normally removed by filtration.

A combination of different cleaning techniques is often applied in the food industry to achieve the goal. For example, potatoes are soaked in water, brushed and then sprayed to effectively remove the adhering contaminants. Similarly, in cleaning grains, especially wheat for the manufacture of flour, several techniques are employed. These include screening, magnetic separation, aspiration and washing before milling into flour.

When wet cleaning is employed, dewatering is essential, since excess water usually has an adverse effect on the subsequent processing steps. Dewatering may be affected at home by using a towel but in the industry where large quantities of raw material are handled, mechanical dewatering equipment is essential. Vibrating screens, dewatering reels, centrifuges or even drying equipment may be employed for this purpose.

3.3 SORTING AND GRADING

Sorting is the separation of raw materials into categories of different physical characteristics such as weight, size, shape and colour, while grading is separation into categories by quality. The two operations together provide a means of segregating raw material into identical lots, which ensure that finished products are also of uniform quality.

In the food industry, where huge quantities of raw materials are handled by machines, sorting and grading form an essential part of the processing. Sorting is one way of ensuring uniformity in quality of finished products. Hence, while the raw material is being sorted, it is partly graded for quality as well. Normally, sorting and grading are carried out as integral operations. However, the finished product is often graded again into one of the several grade categories depending upon its quality. Laboratory tests form a normal part of this final grading exercise. Raw materials are sorted on the basis of weight, size, shape or colour.

3.3.1 Weight Sorting

Weight sorters are machines that weigh the individual item and separate into different categories. Eggs are normally sorted by weight and packed in trays. Some food materials that are sold by weight, e.g., meat cuts, pass through a computer controlled machine which weighs the item, records its weight, computes the price and prints-out a weight label that is affixed to the pack.

3.3.2 Size-Sorting

Size sorting is important for an effective use of processing machinery. Foods of similar size are convenient for mechanized operations like peeling (potatoes), blanching, extraction (oranges juice), canning, dehydration and freezing. A common size sorter used in homes is the fixed aperture screen (sieve) employed for removing tealeaves from prepared tea beverage, or for sifting wheat flour. Similar sieves, called screens, of different dimensions and apertures are used in the food industry. These are operated by electric motors and may have different types of motions such as vibratory, rotary, gyratory, etc. Roller sorters, adjusted to different apertures, are employed, especially for large items such as citrus fruits including orange and Kinnow. These may have a fixed aperture to sort the material into two categories only or variable aperture for separating into several sizes.

3.3.3 Shape-Sorting

Shape sorting is not very common except for removal of contaminants from the raw material. Thus, when grains, such as wheat, have been cleaned of all possible contaminants, some weed seeds may still remain because of their being similar in size and weight to the wheat grains. In this case wheat is passed through shape sorters, which removes all contaminants having the same size or weight but different shape.

3.3.4. Colour-Sorting

Colour sorting is important where uniformity of colour will fetch a higher price for the product. This is carried out with the help of manual labour on inspection belts—a method that is expensive and has several limitations. Electronic colour sorters are in operation that scan the colour of each individual granule with the aid of photocells. The equipment allows materials of the matching colour to pass through while rejecting granules of different colours by means of an air stream.

3.4 PEELING, SHELLING, SKINNING

Nature protects food crops and animals from the attack of external forces by providing a protective covering. This covering known as peel, husk, shell or skin, depending on the raw material, is often inedible and has to be removed. Peeling is commonly practiced in fruits, vegetables and tubers. Several peeling methods are employed. Hand peeling using ordinary or peeling knife requires minimal investment and is only cheap where labour is inexpensive. It has been replaced with more modern methods, though some fruits like mangoes are still hand peeled.

Peeling by heat is advantageous as losses are minimum and the process can easily be automated. In this method boiling water or steam loosen the peel that can be easily slipped by hand or a scrubber or water spray. Flame peelers are employed for peeling onions, garlic, tomatoes and peppers by exposing them to direct flame or to hot gases. Heat causes steam to develop under the skins and puff them so that they can be washed away with water.

Mechanical peeler is more suited to apples, carrots and potatoes. It consists of an upright cylinder, provided in the bottom with a rapidly revolving disc that undergoes undulatory movement (Fig 3.2). The inner walls of the cylinder and disc surface are coated with abrasive carborundum. Continuous abrasive peelers have also been developed. In lye peeling (Fig. 3.2), hot sodium hydroxide solution (1 to 2%) is used for about 30 seconds to 2 minutes or longer, depending upon the raw material. The lye dissolves the peels. This method is suited to all shapes, sizes and varieties. Peeling losses are less as compared to hand peeling and the method is amenable to large-scale production.

Besides these conventionally used methods, a number of new techniques have been developed. These are freeze peeling, vacuum peeling, dry caustic peeling, acid peeling, calcium chloride peeling and ammonium salt peeling. Major emphasis in all the efforts has been to (a) minimize the peel loss, (b) improve the quality of peeled material, (c) reduce pollution of wastewater disposal problems and (d) reduce the cost of peeling. Table 3.1 gives comparative efficiencies of some conventional peeling methods.

Some raw materials e.g., eggs and groundnuts have thick and hard protective covering called shell. Removal of the shell is known as shelling. Some shells, such as are found on coconut, are so hard that considerable mechanical force may be necessary to crack them open.

Peas, pistachio nuts, coconuts, almonds, or walnuts must be shelled to obtain the edible portions from them.

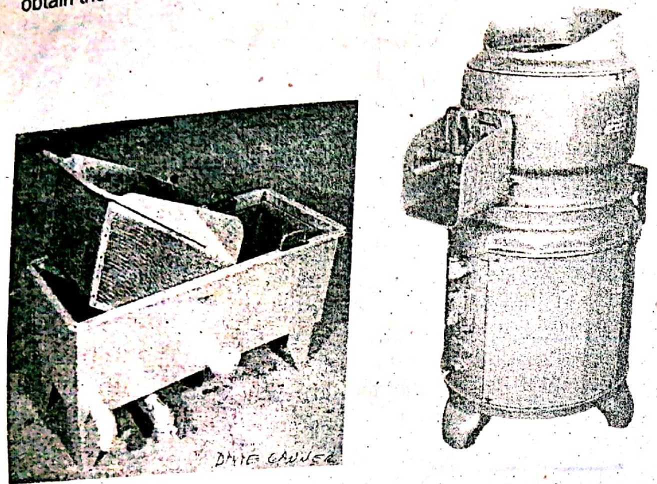

Fig. 3.2 Lye peeler (left) and mechanical peeler (right)
Courtesy: Dixie Canner Equip Co., Athens USA

Cattle, goat and sheep are slaughtered and skinned. Poultry birds are skinned or are defeathered using hot water or dry defeathering methods. In case of fish, scales are removed, while some fish are skinned.

3.5 REMOVAL OF INEDIBLE CONSTITUENTS

Fruits like pineapple have a central core, which although edible in some cases, must be removed during processing. Removal of the core is termed as coring. Dates and plums have pits or seeds located centrally in them. The removal of these seeds is done in an operation referred to as pitting. Some raw materials may be plucked with stems. Examples are tomatoes, strawberries and some vegetables. Removal of the stem is known as stemming and is usually done by hand or vibrating screens. A mild heat treatment (blanching) helps easy removal of stems.

Trimming involves discarding of discoloured, decayed or damaged portions of the raw material and is usually done after other preliminary operations have been completed. Green or under ripe portions, damage/decaying parts, over-ripe and bruised portions of raw materials or the eyes in potatoes are removed during trimming.

Table 3.1 **Peeling methods, process parameters and their efficiency for some fruits and vegetables**

Commodity	Method	Parameters	Remarks
Apple	Lye	10–15% NaOH or KOH at 60–90°C, 4–5 min.	Peel loss 10–12%
	High pressure steam	100 psig 20 sec, lowering to 25 psig and flash cooling with water at 65 psig 15 sec.	Peel loss 2.5%
Peaches	Lye	Spray 10% lye at 63°C, 4 min; 2% boiling lye spray for 38 sec.	For freezing and drying
Guava	Lye	2.0–2.5% boiling lye for 60–90 sec.	
Mango	Hand	Cutting cheeks, quartering and scooping the slice with curved knife	
	Machine	Can peel and cut the cheeks	
Tomatoes	Hot water	100°C, 15–60 sec, cooling and pulling off the peel by hand	
	Steam	Steam for 30–60 sec	Peel loss 7–8%
	Lye	18% NaOH at 88–93°C for 25 sec	Peel loss 7.5%
	Infra-red	816–982°C for 4–20 sec	Peel loss 5.3%
Potatoes	Mechanical	Freshly harvested	No heating
		Cured tough skinned	Peel loss up to 20%
	Lye	5–20% NaOH, 77–99°C for 1–6 min	Peel loss 8–18%
	Flame	1093°C for 15–30 sec	Peel loss 10%
Carrots	Lye	3–10% boiling lye spray	

3.6 SIZE REDUCTION

Size reduction or disintegration is an important operation at home as well as in the food industry and has several functions, viz: -

a. A definite size range may be a consumer requirement, e.g., production of carrot slices or dices.

b. It may help in the extraction of desirable constituents from the raw material, e.g., milling wheat grains for the production of flour or crushing fruits for juice.

c. Size reduction facilitates mixing of various ingredients, as smaller sized particles are easier to mix, e.g., production of cake mixes and baby foods.

d. Some other operations in food processing and preservation are facilitated by smaller sized particles. For example, when potatoes are to be fried or boiled, smaller pieces expose more surface area, hence are easier to process.

In food processing several operations demand prior size reduction of the raw material. Examples are blanching, canning, dehydration, freezing, etc. The type of size reduction treatment given depends upon the kind of raw material, consumer preference and process demand. Thus, in canning, dehydration or freezing of fruits and vegetables, some raw material may be sliced (e.g. carrots, mangoes), diced. (pineapples, potatoes) or shredded (onions, cabbage). When fruits are processed for the production of beverages, the raw material is crushed and squeezed to release juice from the tissues. For some fruits, e.g., mango or guava, a special process known as pulping assembles the fleshy portions

Grain milling also involves size reduction operations. Different fractions of the milled product form special market categories: whole-wheat flour (brown flour), white flour, semolina, etc. form special proprietary products of the wheat grain.

Meat for canning and for use in meat dishes is cut into smaller pieces, while for sausages, burgers and other similar products it is macerated or minced. The minced meat provides a larger surface area, which facilitates mixing of other ingredients and subsequent formation of stable meat emulsion.

3.7 MIXING

Mixing is an operation in which uniform combination of two or more substances is affected. The two components in a mixture may both be solids, or liquids, or one solid and one liquid, and even a gas being mixed with a gas or a liquid.

Powdered solids are mixed together for particular reasons. Powdered skim milk, sugar, cocoa, chocolate, malt extract, processed cereals and flavourings are mixed in the production of baby foods, beverages and other products. In self-raising flours and cake mixes, solid ingredients including white flour, baking powder and other components are mixed together. The most homogeneous mixture is obtained when all ingredients are of similar size, shape and density.

Mixing of two miscible liquids like water and milk does not pose a problem to the food processor. However, immiscible liquids like oil and water are difficult to mix. When these are mixed intimately, the product is called an emulsion. Emulsions can be easily formed between two immiscible liquids when a mutually miscible substance called emulsifier is added to the mixture. Examples of emulsions are homogenized milk, butter, margarine and mayonnaise.

In the manufacture of syrups and sugar-based confectionery, water is mixed with soluble and insoluble solids, respectively. Sugar and common salt constitute soluble solids and will form a homogeneous solution when mixed with water. Starch and wheat flour (called plastic solids) are insoluble and will not mix well with water. For such materials kneading is done to blend thoroughly with water. Production of dough in bread making is an example of mixing insoluble solids with liquid, where the solids absorb water under the influence of mechanical action.

Sometimes gases need to be mixed with liquids. In carbonated beverages, carbon dioxide is mixed under pressure with a homogeneous solution of sugar and other ingredients in water. In the production of omelet, cakes and some types of biscuits, air is incorporated in the eggs by whipping. Similarly, in the manufacture of hydrogenated vegetable oils, hydrogen is mixed with oil in a metal-catalyzed chemical process. The hydrogen is accepted at the double bonds of the unsaturated fatty acids of the oil in the presence of the catalyst, nickel. Mixing of gas with gas poses no problems in the industry, as the gases are readily miscible. In cold storage chambers sometimes an atmosphere of ozone or carbon dioxide is maintained to prolong the shelf life of fresh fruits and vegetables.

3.8 FILTRATION

Filtration is the separation of insoluble components of solid-liquid mixture by passing the same through a material that allows the liquid to pass and retains the insoluble solids. In food industry, filtration is a widely used operation. Water for use as a food ingredient, especially for carbonated beverages, is treated with chemicals to sediment dissolved inorganic materials and filtered before being used in the production processes. In canning, sugar and water are mixed to prepare sugar syrup, while brine is prepared by dissolving common salt in water. In both cases impurities are removed by filtration. In the dairy industry fresh milk is filtered prior to any treatment. Fruit juices, likewise, are filtered to remove coarse particles, skins, seeds and other fibrous tissues.

Depending upon the application, different filter media are employed. At home, one may use cheese-cloth (muslin) for fruit juices. In the industry, filters constructed from porous carbon, porcelain, perforated metal plates, rigid wire meshes or fused alumina find applications. In addition, filters made from silk, wool, cotton or jute are also used. A good filter is one, which will offer minimum resistance to the flow of product and retain maximum residues. It has also to be non-toxic and relatively inexpensive.

Sometimes when large quantities of a product are required to be filtered, the filter surface may get blocked, especially when the solids are very finely divided or are of a slimy nature. In such cases substances known as filter aids are employed. They help to retain the porousness of the filter thereby facilitating filtration. Examples of such substances are kieselguhr, diatomaceous earth and activated charcoal.

3.9 PREVENTION OF ENZYMATIC BROWNING

In certain plant foods enzymes promote discolouration, especially after these have been peeled or injured. These enzymes catalyze the oxidative polymerization of polyphenolic substrates contained in the food. The polymerized products of this complex reaction give rise to browning as observed on the surface of cut potatoes, bananas and apples after exposure to air. At home, such reactions are avoided by promptly dropping the material in water soon after cutting. Changes in colour (browning) are prevented by mild heat treatment called blanching or by the use of certain chemical substances.

3.9.1 Blanching

Blanching (also known as scalding) is the heating of some plant food materials in hot water or live steam for a very short time (ranging from few seconds to a few minutes) mainly to destroy active food enzymes. However, blanching also serves to: -

a. Loosen the skin, e.g. tomatoes.
b. Clean the product by helping to remove adhering contaminants such as soil, insects, microorganisms, etc.
c. Remove tissue gas from leafy vegetables (e.g. spinach), thereby reducing their volume and facilitating close filling.
d. Fix the green colour in vegetables (peas, spinach).
e. Remove slime-forming substances in vegetables (okra).

At home, blanching is done by dipping freshly prepared (peeled, sliced, diced) raw material in boiling water for 2 to 5 minutes. In the industry, prepared raw material is exposed to steam in a blancher for similar period (Fig. 3.3).

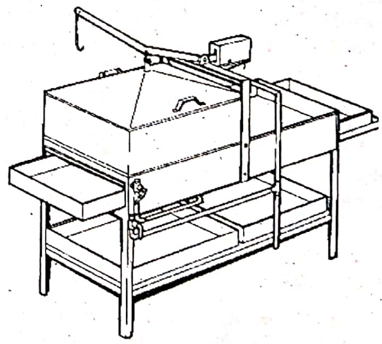

Fig. 3.3
Tray type steam blancher

The effectiveness of blanching is determined by evaluating the activity of peroxidase or catalase, as these are the most heat-resistant and widely distributed in plant tissues. The heating time required to destroy these enzymes depends upon several factors such as the type of raw material, size of particles and heating method. In general, at 100°C peas require from 1 to 1½, spinach 1½, green beans from 1 to 4, okra 1 – 2, mushrooms 4 – 5 and turnips from 3 – 4 minutes.

Quite often certain chemicals are added to blanching water to improve the effectiveness of the process. Calcium chloride is added to firm fruits. Ascorbic acid, sodium chloride, magnesium oxide, sodium metabisulphite, potassium metabisulphite, sodium bicarbonate and others are useful in the preservation of colour and retention of vitamin C.

3.9.2 Use of Chemicals

Control of polyphenoloxidase in some fruits usually cannot be achieved by heating, since heat damages some desirable sensory properties. Chemical substances are, therefore, utilized to retard enzyme catalyzed oxidative browning. These serve to inhibit enzymes, alter substrates, or limit entrance of oxygen. Among these are sulphur dioxide (sulphites and sulphurous acid), some organic acids (e.g., citric and malic), ascorbic acid and sugar.

Sulphiting agents, such as sulphur dioxide and salts releasing this gas (Na– or K–metabisulphite), are highly effective in controlling both enzymatic as well as non-enzymatic browning. They also check the growth of microorganisms, act as bleaching agents, antioxidants or reducing agents and carry out various other functions. Sulphites interact with the enzyme or substrate. The raw material, e.g. grapes for drying, is exposed to SO_2 fumes generated from burning sulphur in a closed chamber. Because of the inherent side effects introduced when SO_2 gas is used, dipping in solutions of Na- or K-metabisulphite is preferred. In this case SO_2 is released much more slowly, the bleaching action is minimized and the apparent toxicity and bad taste often associated with high levels of the gas are avoided. Sulphur dioxide or matabisulphite treatment has certain limitations. Besides being toxic to the workers (implicated as initiator of asthmatic reactions), it bleaches natural colour of some fruits and may cause corrosion of cans. It is discouraged for fruits and vegetables that serve as major sources of thiamine, since this vitamin is destroyed by these chemicals.

Ascorbic acid is the best-known alternative to sulphites. It is effective in controlling enzymatic browning by maintaining phenolic substances in reduced and colourless state. Concentration of about 0.3% ascorbic acid in sugar syrup is usually required for complete effectiveness. However, lower concentration (about 0.1%) is frequently used. Sugar syrup lessens enzymatic browning by acting as a barrier to the entrance of oxygen. The organic acids lower pH to a value less suitable for enzyme activity.

4

USE OF HIGH TEMPERATURE

Heat energy is widely used for food processing and preservation. In cooking, it increases the digestibility of some nutrients, while in heat processing, it is aimed at destroying pathogenic and spoilage microorganisms. Various techniques and processes in which heat energy is applied in the form of high temperature include cooking, blanching, pasteurization and sterilization.

4.1 COOKING

Cooking, as applied broadly, includes heating food in order to alter its colour, flavour and texture. It more importantly improves the digestibility of the food components. During this process, enzymes and microorganisms are also destroyed. Foods cooked at home do not keep for long time since these are always left in utensils that are not hermetically sealed and cannot prevent recontamination. Cooked foods have a comparatively longer shelf life than the uncooked ones.

Cooking embraces different forms of heating methods such as baking, boiling, broiling, roasting, frying, stewing and steaming (Table 4.1). Broadly speaking, it may be done by direct exposure of food to a source of heat (dry cooking – grilling, roasting). Food may also be cooked in a suitable liquid medium such as water, steam or cooking fats. In boiling, stewing and steaming, the process is carried out at boiling temperature of water or higher if pressure cooker is employed. Baking, broiling and roasting employ dry heat, while in frying, the process is conducted in fat or oil and as such temperatures much higher than 100°C are attained.

Table 4.1 Cooking methods

Cooking method	Description
Baking	Cooking in an oven with dry heat (100 – 232°C)
Barbecuing	Direct heating over glowing, smokeless wood fire
Boiling	Cooking in a liquid, usually water (100°C)
Braising	Short frying followed by stewing
Broasting	Pressure frying
Broiling	Cooking under or over direct rays of heat
Frying	Cooking in heated fat or oil (160° – 200°C)
Grilling	Cooking by radiant heat from below or above
Infrared cooking	Cooking by infrared rays
Microwave cooking	Cooking by microwaves (high frequency power)
Poaching	Cooking in a minimum volume of water at slightly below boiling temperature of water (85–91°C)
Pressure cooking	Cooking by steam under pressure (115–121°C)
Roasting	Cooking by dry heat in oven or closed vessel with just a little fat
Sauteing	Frying lightly and quickly in a small quantity of oil – a kind of semi-shallow frying
Simmering	Cooking in water with gentle heating
Steaming	Cooking in steam (100°C)
Stewing	Simmering in a small amount of water in a covered saucepan or casserole

4.2 BLANCHING

Blanching is commonly applied to plant materials to destroy some enzyme systems prior to canning, cold storage, freezing or dehydration. Heat energy is applied through the medium of water or steam. This has been explained in Chapter 3, Preparatory Operations in Food Processing, Section 3.9.1.

4.3 PASTEURIZATION

Pasteurization is a heat treatment designed primarily to kill vegetative forms of microbial cells in liquid foods. The object of this treatment varies from food to food, but invariably all pathogenic and non-sporing organisms are eliminated, e.g., in milk the object is to destroy pathogenic bacteria, especially *Mycobacterium tuberculosis* which is responsible for tuberculosis in man. The pasteurization temperature varies with the type of food and the length of time it is to be exposed to that particular temperature. The heat resistance of the spoilage or pathogenic microorganisms required to be killed in the process also governs it. Usually pasteurized foods, which show only reasonable extended shelf life, are supplemented by other methods of food preservation such as storage at low temperature or sealing in anaerobic environment. Two types of pasteurizers, continuous and discontinuous or batch type are in use.

4.3.1 Continuous Pasteurizers

Continuous pasteurizers consist of a single metal tube or series of hollow, jacketed plates or small metal tubes through which the liquid food flows. It is heated to the desired temperature by steam or hot water that passes through a jacket. Plate pasteurizers are generally used in preference to the tubular type, which can only be cleaned in-line. The food may be heated in these pasteurizers at low temperature for long-time or high temperature for a short time, hence the names low-temperature-long-time (LTLT) and high-temperature-short-time (HTST).

In the LTLT process, usually a temperature between 65 to 75°C is employed. Most fruit juices are held for about 20 minutes. In the HTST process, comparatively higher temperatures are used and food is held for a very short time. Milk, for example, is pasteurized at 72°C for 15 seconds and fruit juices at 82 to 91°C for a few seconds. In the ultra high temperature (UHT) process (also called flash pasteurization), the fruit juice may momentarily be subjected to 116°C and cooled to 88°C before filling. Higher temperatures for short periods, while being effective in destroying microorganisms, are less efficient in bringing about adverse changes in food components. In the LTLT process, greater damage to food constituents is likely to occur than in the HTST process.

The food may also be pasteurized after being filled into bottles or cans. Normally this is a continuous process and is done mostly in hot water bath or an atmosphere of live steam.

4.3.2 Discontinuous Pasteurizers

The discontinuous pasteurizers consist of steam jacketed kettle or tank equipped with steam coils in which food (juice, milk) may be placed and heated to the desired temperature for the required length of time. The disadvantages in this type are that local overheating of small portions may occur. Moreover, food is exposed to oxidation during the process. Prolonged heating causes injury to colour, flavour and nutrients of the product.

4.4 CANNING/ sterrilization.

Canning is the method of food preservation in which food contained in a permanently sealed container is subjected to an elevated temperature for a definite period of time and then cooled. The spoilage organisms present are destroyed by heat and the hermetic seal of the container prevents fresh contamination. All microorganisms that might have survived the rigours of processing are unable to grow because of unfavourable conditions prevailing inside the container. In special canning techniques, heating of food is done before filling it into pre-sterilized containers. The traditional method of canning involves several distinct unit operations.

4.4.1 Preparation of Raw Materials

All raw materials require some sort of preparation to make them fit for human consumption. The food processor ensures that these are properly handled, sorted, and inedible parts removed through peeling, pitting, coring, stemming, trimming, shelling, dressing, etc. (see Chapter 3). The size is reduced to suit the consumer demand, market requirements and heat processing parameters.

Fruits and vegetables are washed, normally peeled (leafy vegetables stemmed), and seeds and other inedible parts removed. Some fruits may be halved (guava, pears); others are sliced or diced (mango, banana, pineapple). Animals are slaughtered, bled, skinned and carcass cut into small pieces. Birds are slaughtered, defeathered and eviscerated. Fish is eviscerated and cut into small pieces (tuna) or packed whole (sardines).

Some fruits and most vegetables are blanched to inactivate food enzyme systems (see Chapter 2). These may also be treated with sulphites or other chemicals. No such treatment is required for beef or mutton. The birds (chicken, duck) may be passed over a flame to singe off the tiny hairs that remain after removal of feathers.

4.4.2 Filling

The cans or glass jars are normally washed by subjecting them to steam jets prior to filling. This process ensures removal of adhering contaminants.

Filling is done manually or by automated machines. At home, all products are filled into the containers manually, while the industry employs both manual and automated filling techniques depending upon the raw material and grade of the product. Fancy grades are still filled manually, while automated machines are employed for most fruits and small vegetables. Liquid products (milk, carbonated beverages, fruit juices, squashes) are invariably filled by automated machines in the industry.

4.4.3 Syruping and Brining

The spaces in between the pieces of food are filled by a suitable liquid to facilitate further processing. In case of fruits, sugar syrup is used, while in vegetables and meat, brine is added. Fish is usually canned in brine and oil or tomato sauce. Apart from facilitating heat transfer during processing, this liquid improves the taste of the canned product and fills up the inter-spaces between food pieces, driving the air out. It can also be used as a carrier of additives such as colour and flavour.

The syrup or brine is filled in the containers at a temperature of 79 to 82°C, because the hot liquid helps to drive out some of the entrapped air. Suitable headspace, 0.3 to 0.5 cm (1/8 to 3/16 inch) is left in the can or jar so that when the closure is finally accomplished, this space will help in further processing (create vacuum and reduce strain on the container during heat processing). The syrup or brine is usually filled into the cans or jars by automated machines, while it can be done manually at home.

Syrup for use in fruit canning is prepared by dissolving sugar in hot water. Unrefined sugar should be avoided, since it contains sulphur that forms hydrogen sulphide and results in a black deposit of metallic sulphide in the cans. This also hastens corrosion of the cans. Concentrations of sugar syrup that vary from product to product and grade to grade, usually range from 20 to 40%—higher concentration is used for expensive grades and lower for cheaper grades of the product. Sometimes in canning of fruit pieces, e.g., pineapple slices or mango cheeks, the processor may prefer to add some fruit juice (obtained as a by-product) to reduce the cost of sugar and to add extra natural flavour to the product.

Concentration of sugar in the syrup is measured using different instruments and scales. Brix and Balling hydrometers give percent sugar in syrup. While Brix scale is calibrated to read percent by weight of sucrose in a solution at 20°C, Balling measures the same at 17.5°C. The Baume hydrometer has a scale ranging from 0 to 70 degrees. The relation between Brix and Baume scales and specific gravity is given in Table 4.2. Different types of refractometers are also in use that employ the principle of refraction to measure sugar concentration in solutions. The Abbe refractometer is the most widely used in canneries. The hand refractometers give sugar concentration at room temperature, while table models can be adjusted to any desired temperature.

Table 4.2 **Relationship between Brix, Baume and specific gravity of sugar syrups**

Degrees Brix (% sugar by weight at 20°C)	Degrees Baume (at 20°C)	Specific gravity (at 20°C)
10	5.6	1.040
15	8.3	1.061
20	11.1	1.083
25	13.8	1.106
30	16.6	1.129
35	19.3	1.153
40	22.0	1.179
45	24.6	1.205
50	27.3	1.232
55	29.9	1.260
60	32.5	1.288
65	35.0	1.319
70	37.6	1.350

In canning of vegetables, brine or common salt solution is added. The salt should be at least 99% pure NaCl. Iron compounds in the salt cause discolouration of brine and result in blackening of the product.

Calcium salts give a white precipitate. The brine is tested by a hydrometer commonly called Salometer. A brine solution containing 26% salt will gives a Salometer reading of 100 units. The concentration of common salt varies from 1 to 3% depending upon the product. In some products such as corn and peas, the brine may contain a small amount of sugar, usually between 3 to 10%. Sugar improves the taste by its mellowing action on salt.

4.4.4 Lidding and Clinching

After filling syrup or brine into the can, the closing end or lid is placed on the open end of the can without sealing it to rest of the can body. This process is known as lidding (Fig. 4.3). However, during the subsequent exhausting operation, there is a danger that the lid may fall off and can contents spilled over. To avoid this, some canners prefer to clinch the lid to the can body. In this operation the curl of the can end is engaged with the flange of the can (Fig 4.3) by action of the first set of rollers in a double seamer (Fig 4.1).

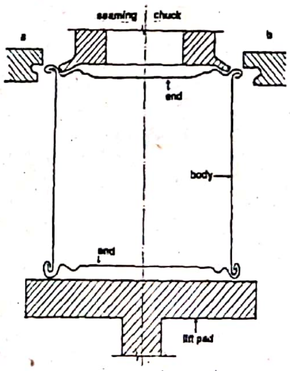

Fig 3.1 Basic seamer design showing the position of the first operation sealing roller (a) and the second operation seaming roller (b).

4.4.5 Exhausting and Vacuuming

The can contents contain air in the spaces between food particles and the tissues of the product. The air in the can causes corrosion of the tin plate; aids oxidation processes in food and encourages germination of bacterial spores that survive commercial sterilization. It is, therefore, undesirable to leave air. When air is removed either by exhausting or by mechanical means, a vacuum is created inside the can and the ends remain concave. This gives the consumer an indication of soundness of the contents since production of gas and bulging of the can ends accompany some kinds of spoilages of heated canned foods. Vacuum also prevents undue strain on the can during subsequent heat processing.

Different equipment are used for exhausting. A simple exhaust box consists of a narrow, shallow, rectangular metal box though which passes a steel cable that carries the cans (Fig 4.2). This type is known as the cable exhaust box, while a modification of this has the cable replaced by a chain conveyor. The speed of the cable or chain is regulated depending upon the size of the container and type of the product. The cans are carried through an atmosphere of live steam that is allowed into the exhaust box through openings at various points in the equipment. Another type is the disc exhaust box that consists of rectangular metal box in which several rows of large metal discs are fitted. Curved iron rods above the discs guide the cans through the equipment that travel down one row of discs and back the next. The number of rows and the length of exhaust box vary according to the capacity desired and the nature of product to be exhausted.

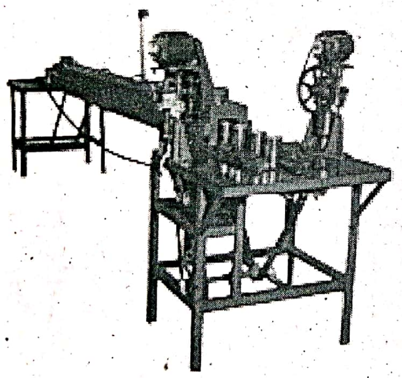

Fig. 4.2 A simple exhaust box with can sealing machine.
Courtesy: Dixie Canner Equipment Co., Athens, USA.

The usual exhausting temperature for fruits is 82 to 96°C inside the exhaust box. When the can centre temperature reaches 77 to 82°C the cans would have been exhausted. The length of time depends upon the type of product and type and size of the container. Exhausting temperatures for some selected fruits and vegetables are given in Tables 4.3 (page 42) and 4.4 (page 43).

In many modern canneries, steam flow closure or vacuum closing machines have replaced the exhaust box. Both these help to create vacuum in the can.

At home, two different arrangements can be made to remove air from the food. The prepared material (apple slices or mango pieces) is placed in a vessel and syrup added. This is heated to the desired temperature (82 to 96°C) and filled hot in the cans or jars. These are then sealed immediately. The steam that appears at the surface leaves a vacuum after condensing. In the second arrangement, food is placed in the container and syrup or brine is added (headspace must be left). The containers are placed in water bath, the level of water being about 2.5 cm below the top of the jar or can. The water is heated to the desired temperature for specific time and the containers are sealed airtight. Only acid and high acid foods should be canned or bottled at home and processing of low and medium acid foods be left to the experts.

4.4.6 Sealing

As soon as cans emerge out of the exhaust box, these are hermetically sealed with the help of a can-sealing machine, called the double seamer. A hermetic seal consists of a double seam. In the first seaming operation, the curl of the can end is engaged with the flange of the can. A good first operation seam has the body hook approximately parallel to the cover hook. The second operation is designed to compress and smooth out the first operation. During both operations, considerable pressure is exerted on the can end, the can body and the sealing compound. This pressure forces the sealing compound into the voids of the seam. This forms a strong mechanical structure that is air- and water-tight (Fig. 4.3).

When the products are packed in glass container, the cap may be screwed on. Some jars are sealed under vacuum—the vacuum inside the jar retains the cap in such cases.

4.4.7 Heat Processing

Heat processing, as applied in canning, means heating food at a certain temperature for sufficient length of time to render the contents stable against pathogenic and spoilage microorganisms. In food processing industry moist heat is employed for the destruction of microorganisms. However, absolute sterilization is difficult to achieve with foods since the temperature/time conditions which bring about this, grossly damage food texture and nutrients.

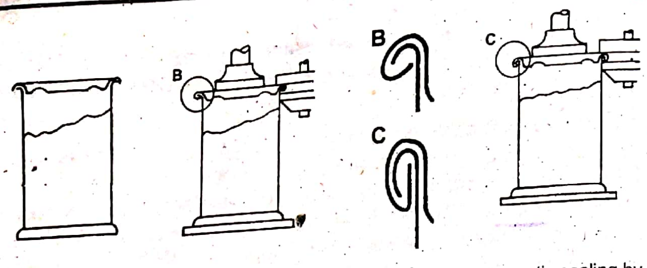

Fig. 4.3 Steps in the formation of a double seam.

The food processor aims at maintaining a balance at which maximum numbers of microorganisms are destroyed and minimum nutrients are adversely affected. This is referred to as commercial sterilization or heat processing. This may be defined as a treatment aimed at destroying all pathogenic and most spoilage organisms at the cost of minimum damage to food texture and nutrients. Additionally, microbial spores that are likely to thrive under the subsequent handling and storage conditions must also be eliminated. Microorganisms that survive the heat processing operation are unable to cause any trouble, since other treatments that have been given to the canned food render them dormant.

4.4.7.1 Objects of heat processing

The primary object of heat processing is to ensure that all health hazards are controlled and that, the shelf life of food products is prolonged. Additionally, heat processing improves texture, flavour and appearance of the product by cooking. In case of vegetables, meat and other similar foods that are required to be cooked for consumption, heat processing shortens the subsequent cooking time at home.

4.4.7.2 Factors affecting heat processing of foods

The success of canning depends on how heat processing is performed, as well as the degree of vacuum inside the container and the quality of the seal. Heat processing of foods depends upon two major factors that determine the processing requirements of a particular food. These are lethality of microorganisms and heat penetration through the container and its contents.

a. Lethality of microorganisms

Nature and number of microorganisms, the environmental conditions in which microorganisms are to be heat processed and the time/temperature relationship affect lethality of microorganisms during heat processing.

Nature and number of microorganisms – Broadly speaking, microorganisms important in food processing are yeasts, moulds and bacteria. Yeasts and moulds are easily killed, while bacteria are more heat resistant and require longer time or higher temperatures for their destruction.

Microorganisms live in different physiological states. They may exist as very young cells, older cells and in case of spore formers, as spores. Young cells are easiest to destroy by heat followed by older cells; spores are most resistant and hence are difficult to kill. Therefore, a food material containing mature cells or spores will require a severe heat treatment for the thermal destruction of the organisms.

The number of microorganisms present in a particular medium for heat processing has a direct relationship with their destruction. Microorganisms multiply and die in logarithmic order. This means that a certain percentage of the population will die in a particular period and the same percentage of the surviving population will die in the next equivalent period, and so on. Hence, greater the number of organisms, longer will be the time required for their destruction. It is, therefore, important that the raw material used for heat-processed foods is not heavily contaminated, decomposed or over-ripe.

Environmental factors – The composition of food materials affects heat resistance of microorganisms. Inorganic salts can increase or decrease their heat resistance. Fat, proteins and proteinaceous substances provide some protection to the cells and spores and thus increase their heat resistance. Sugar, likewise, increases the heat tolerance of microorganisms, especially of yeasts and moulds.

The viability of microorganisms is influenced by the pH of the food. For most spore-forming bacteria maximum heat resistance occurs near neutral pH. Hence bacterial spores are more easily destroyed in fruit products at pH 3.0 than in meat or vegetable products at pH 5.0 or above. It has been established that all foods with a pH value of below 4.5 (fruits, fruit products) can be heat processed at 100°C. Others like chicken, meat, fish or vegetables whose pH exceeds 4.5 (medium and low acid foods) must be heat processed at 100°C or higher.

One reason for limiting the temperature to 100°C for heat processing of acid and high acid foods is that the acid in the food retards the growth of non-aciduric bacteria and their spores that may survive heat treatment at this temperature. Secondly, even if the spores are not destroyed, these will do no harm as they cannot germinate in such products (since one requirement for spore germination is suitable pH, above 4.5). Moreover, microorganisms do not usually thrive in heavy sugar syrups that are commonly used in canning of fruits. On the other hand, low and medium acid foods like meat and vegetables are contaminated with heat resistant forms from animal body, intestines, soil, etc. Therefore, higher temperatures are needed to heat process them. For practical purposes, in heat processing the food processor regards pH 4.5 as the dividing line between foods that can be heat processed at either 100°C or above.

Time and temperature relationship – The destruction of microorganisms depends, in part, upon the length of time they are exposed to a particular temperature. Yeasts and moulds are easily destroyed at 100°C or slightly lower, while bacteria and their spores require higher temperatures. The destructive effect of heat rapidly increases as the temperature rises. Hence, heat processing at 121°C is much quicker than at 100°C. For instance, in low acid media *Clostridium botulinum* spores are destroyed at 100°C in 330 minutes while at 115.5°C they require only 10 and at 121°C just 2.79 minutes. It is less harmful for the food to be exposed to high temperature for a short time, than to low temperature for long time.

The time required to kill microorganisms at a given lethal temperature is known as thermal death time. The relationship between the number of survivors and time of exposure at the lethal temperature is very similar for all microorganisms. This has enabled preparation of thermal death curves for target organisms (Fig 4. 4). Thus, mathematically speaking, logarithm of the number of survivors is a straight-line function of time and its horizontal displacement varies as different organisms or diverse foods are considered.

b. Heat penetration through containers and contents

The effectiveness of heat processing of foods largely depends upon the degree of heat penetration from outside inwards through the container into its contents. The heating characteristics of the contents influence the thermal destruction of microorganisms. Foods are normally heat processed in hot water or live steam The factors that affect heat penetration into the food are: -

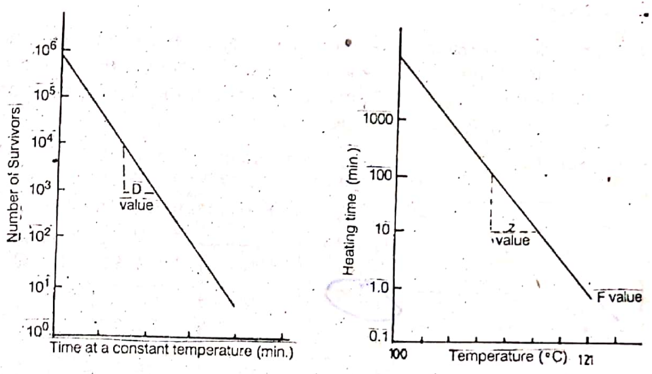

Fig. 4.4 Thermal death rate curve (left) and thermal death time curve (right)

Nature and size of container – Conventionally in canning, glass and tin are commonly used in container manufacture. Glass is a bad conductor of heat and, therefore, food packed in it will take longer time to heat process than in a similar sized tin can. Pouches take still less time. Aluminium foil, plastic films and other flexible materials are also employed for packaging. Usually such foods are first heat processed and then aseptically filled in these containers.

Since heat has to travel from outside to inside the container and reach all parts, larger containers require longer time for heating than smaller ones: the distance from the surface of a large container to the centre is greater than in a small one. This problem posed by the container size is, in part, eliminated by the agitation provided in agitation-type retorts.

Kind and consistency of food – Liquid (condensed milk, fruit juices), semi-solid (baby foods) or solids suspended in syrup or brine (apple slices, green beans), or solid pack (meat, spinach) are canned in the industry. Heat processing of each varies according to heat conductivity of the foods. Compactly packed solid food requires longer processing time at the same temperature than the same food packed loosely in some liquid; liquid foods need much less time to attain particular temperature under similar processing conditions. Tables 4.3 and 4.4 provide recommended heat processing parameters for fruits and vegetables in still retort.

Type of processing equipment - Since heat has to reach all parts of the can contents, the type of processing equipment would affect the heat penetration. Agitating retorts are more efficient than still types in achieving the same goal.

Table 4.3 **Exhausting temperature and heat processing requirements for some selected fruits.**

Product	Exhausting Temperature (°C)	Processing time (minutes) of cans at 100°C		
		No. 2	No. 2½	No. 10
Apples	88	10	15	20
Apricots	71	25	35	40
Grapes	77	12	15	20
Guava	88	16	20	25
Mangoes	77	15	20	30
Peaches	71	25	35	45
Pears	71	20	30	40
Pineapples	71	20	30	40
Plums	82	15	20	35
Strawberries	77	8	8	10
Tomatoes	60	10	10	15

4.4.7.3 Processing methods and equipment

Basically, there are two methods for obtaining commercially sterile foods: aseptic canning and conventional canning. In aseptic canning, food is first heat processed and then filled or packaged aseptically into suitable sterile containers. It is also employed in the HTST method, in processes designated as aseptic canning and in

pasteurization and sterilization utilizing microwave heating. The use of this principle is seen in the processing of fruit based beverages, fluid milk and most fluid foods.

Table 4.4 **Exhausting temperature and heat processing requirements for some selected vegetables.**

Product	Exhausting Temperature (°C)	Processing time (minutes) of cans at 100°C		
		No. 2	No. 2½	No. 10
Beans, green	60	18	25	30
Brinjal	71	25	30	60
Cabbage	66	35	25	40
Carrots	66	20	20	27
Cauliflower	66	20	20	30
Mushrooms	66	25	30	50
Okra	77	20	25	35
Peas, green	60	15	18	23
Potatoes, sweet	77	40	45	60
Potatoes, white	71	20	25	32

The commercial thermal processing is conventional canning process in which food is filled into the container, which is sealed hermetically and then subjected to high temperature. It may be accomplished in any of the many available heat exchange devices: -

a. Open cookers.

b. Retorts.

c. Hydrostatic cooker and cooler.

d. Direct flame sterilizers.

The open cookers are used for heat processing of acid and high acid foods by the small and home-scale processors as well as some large units. The equipment consists of open metallic pans or tanks of appropriate size filled with water. The water temperature is maintained at boiling by suitable means such as firewood, coal, gas, electricity, steam coils or open steam jets. Heat transfer is more efficient in the agitating types than in the still cookers.

Retorts are pressure cookers in which foods are processed in water at higher temperatures than attainable at atmospheric pressure. Different retorts are in use, primarily for processing low and medium acid foods packed in metal and glass containers. A conventional still retort is basically a discontinuous, non-agitating type of vertical (Fig. 4.5) or horizontal vessel that is used for heat processing of canned foods under pressure.

The efficiency of retorts has been greatly increased by providing agitating movements inside the equipment. For example, heat processing of evaporated milk requires 18 minutes at 115.6°C in a still retort while in the agitating type 2.25 minutes are needed to achieve the same results at 93.3°C. The modern retorts are fitted with several gauges and controls (air vent, temperature and pressure gauges, etc.). All air from inside the retort must be removed, since it is a bad conductor of heat and will act as an insulator during the heat transfer operation. Moreover, air in the presence of moisture at high temperatures, causes steel cans to rust.

The hydrostatic cooker and cooler is basically a still retort operating at a constant steam temperature through which the food containers are transported for the required process time by conveyer system. The equipment comprises of a feed and discharge station, in-feed section, feed leg, steam dome, and discharge leg. The water heads in the feed and discharge legs provide the pressure necessary to balance the constant steam pressure in the steam dome. This type of cooker is efficient but expensive to operate.

Direct flame sterilization of foods in tin cans has been successfully achieved with small sizes only. The cans are conveyed across a bank of gas burners operating at about 1093°C. Applications of this system are somewhat limited.

4.4.8 Cooling

During heat processing, the temperature of food inside the can reaches 100°C or higher. If the cans are held at this temperature longer than necessary, the heat energy will cause damage to the nutrients. To avoid unnecessary nutrient loss and over-cooking of the food, the cans must be cooled to around 43°C. This temperature ensures that after cooling operation the cans will be dried by their own internal heat,

thereby preventing can rust as a result of moisture adhering to their bodies.

In most modern retorts, arrangements exist for subsequent cooling after heat processing. Glass containers, if processed in retorts, are also cooled in them. On a small scale, cooling may be accomplished by sprays of cold water or passing the containers through a tank of running cold water or even by exposing them (and especially glass containers) to properly circulating air.

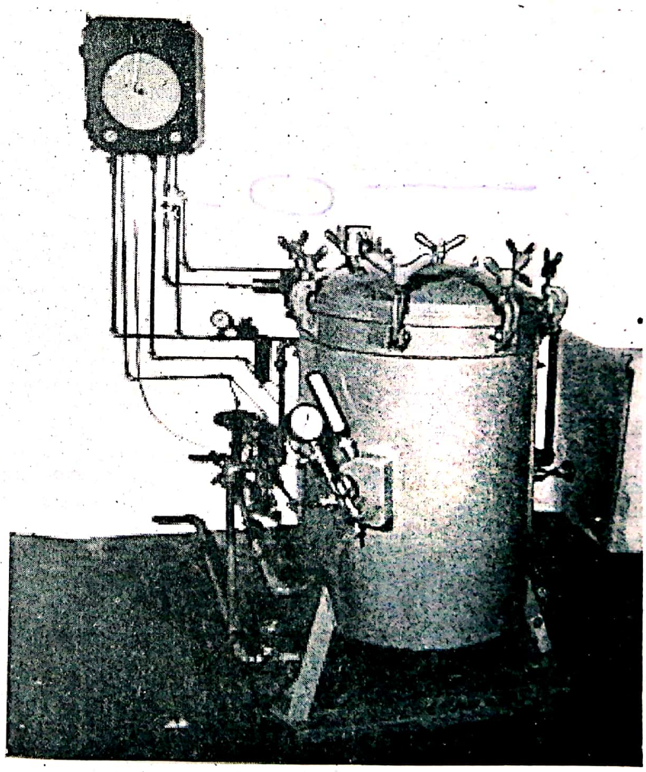

Fig. 4.5 A vertical still retort for heat processing of foods at above 100°C.
Courtesy: Dixie Canner Equipment Co., Athens, USA

4.4.9 Labelling

Almost all modern cans come with a printed can body. However, some factories prefer to use labels printed on a paper. For home-scale processing and in small factories, printed labels are widely used. After the cans have been cooled and dried, they are labelled. The commercial food processor uses a printed label and prefers special labelling machines to do the job. The home-scale processor writes the label indicating the product and date, and pastes it to the container with suitable glue.

4.4.10 Storing and Packing

Although proper heat processing of canned food ensures safety against spoilage, yet some chemical reactions, and in some cases microbial attack, can still occur in the product if it is stored at high temperatures. Microbiologically speaking, commercially sterile cans may contain some viable bacterial spores that may constitute a source of spoilage if held at a temperature of 37°C or above. This information is particularly important in Pakistan where warehouse temperatures are often quite high during summer months. It is, therefore, recommended that canned foods be stored in a cool, dry place, whether inside the house or in the warehouse. If storage temperatures in excess of 37°C are expected in the environment, then heat processing should be more drastic to ensure the destruction of all organisms capable of activity at these high temperatures. This will provide a longer shelf life to the product even though slightly more nutrients will be damaged during such a heat treatment.

For shipping to far off places, several cans are packed into suitable sized cartons. In large processing plants this job is also done by machines, while a small-scale processor can utilize manual labour.

"BOOKS, LIKE FRIENDS, SHOULD BE FEW AND WELL CHOSEN"

5

USE OF LOW TEMPERATURE

The activities of food spoilage agents are very much dependent upon temperature. Enzymes require particular optimum temperature for their catalytic reactions; so do the microorganisms for their activities. Even the rate of pure chemical reactions is influenced by temperature, but these are not terminated as easily as enzyme-catalyzed reactions when temperature beyond the optimum range is encountered.

Temperature manipulation is a very useful tool for extending storage life of foods. When enzyme and microbial activities are undesirable in foods, temperature control may become necessary. Keeping food above the maximum temperature required for enzyme and microbial activity may mean encouraging chemical reactions as temperature is increased. Moreover, the nutritional quality of food is damaged if it is stored at a high temperature for a long time. The alternative procedure for checking the problems posed by enzymes and microorganisms is to hold food at temperature below the minimum for their activities. Low temperature also retards simple non-enzymatic chemical reactions in foods.

Normally enzyme activity and growth of food spoilage and pathogenic organisms best proceed at moderate temperature, i.e., in the mesophilic range. Progressive reduction in temperature below this initiates gradual decrease in the activity of food spoilage agents. Below a certain temperature, all life activities cease and so food is saved from deterioration and spoilage. The choice of temperature usually depends upon the objective of storage. If short-term storage is the aim, then the temperature could be decreased to near or slightly below the minimum required for the enzyme and microbial activities. In case food is to be stored for a long period, then the temperature has to be reduced far below the minimum at which any life activity can occur.

The terms cold storage and freezer storage, respectively, describe storage under the two situations. Cold storage refers to the storage condition where food is held at temperature above its freezing point. Freezer storage, on the other hand, describes the situation where food is held in frozen state at temperatures lower than the freezing point, which incidentally corresponds to temperatures far below the minimum conducive for the activities of enzymes and microorganisms.

5.1 EQUIPMENT

The equipment required in low temperature storage installations is basically a refrigeration system whose power may be through non-mechanical or mechanical means. In the non-mechanical or natural systems, ice or a suitable freezing mixture is employed. In mechanical refrigeration systems, the liquid refrigerant that boils and vaporizes at very low temperature, circulates in a closed system. It absorbs heat from its environment and is transformed to the gaseous state. The gaseous refrigerant is reconverted into liquid state through a suitable mechanism that may involve either a 'vapour absorption cycle' or a 'vapour compression cycle'. In systems using the vapour absorption cycle, the refrigerant moves from the liquid phase to the gaseous state: the gas is absorbed in a suitable fluid and the liquid refrigerant is regenerated. This is employed in the manufacture of domestic refrigerators that work with gas, kerosene or other similar source of heat.

Refrigerators using the vapour compression cycle employ a device, the 'compressor' to bring about the compression of the gaseous refrigerant. The electrical household refrigerators, freezers and common commercial equipment are of this type. In its simplest form, a vapour compression mechanical refrigeration system consists of four basic components—compressor, condenser, expansion valve and evaporator (Fig. 5.1).

The compressor is the heart of the system and provides energy for its operation. It compresses the gas circulating in the hermetically sealed refrigeration system and passes it to the condenser. Here the gas is cooled and condensed to liquid form. The liquid refrigerant is passed to the evaporator at a high pressure through an expansion valve that

results in changing the fluid refrigerant to an atomized vapour-liquid mixture at low pressure. In the evaporator the refrigerant obtains heat from the surrounding atmosphere and vaporizes. The gaseous vapours again pass through the compressor and the cycle is repeated.

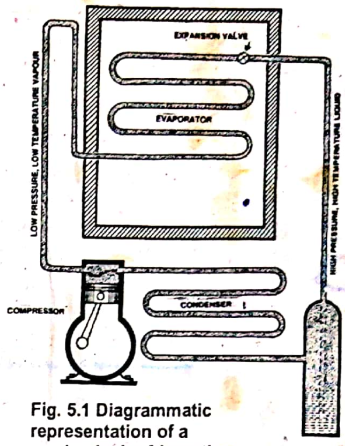

Fig. 5.1 Diagrammatic representation of a mechanical refrigeration system

5.2 REFRIGERATION SYSTEMS

Refrigeration systems are generally classified into three groups based on the operating temperatures attainable: -

a. **High temperature systems** – used for air conditioning and cold storage equipment where temperatures between –3.9°C (25°F) to 7°C (45°F) or higher are needed.

b. **Medium temperature systems** – these are used for food storage and other applications requiring temperatures between –3.9°C (25°F) and –17.8°C (0°F).

c. **Low temperature systems** – employed where temperatures of –17.8°C (0°F) or lower are needed.

5.3 USE OF ABOVE FREEZING TEMPERATURE

The simplest form of equipment available for storage of foods at above freezing temperature is the domestic refrigerator and food displaying cabinets installed in supermarkets. In this equipment, temperature is lowered by the use of vapour compression mechanical refrigeration system. The shelf life of food commodities is short in these than when the same commodities are stored in commercial cold stores equipped with other sets of controls.

The commercial cold stores operating in Pakistan are large insulated rooms equipped with a mechanical cooling system that lowers the temperature of the chamber. The controlled atmosphere storage facilities (CA storage) are equipped with other mechanisms whereby humidity, ventilation and composition of gases inside the chamber may be regulated. These provide optimum conditions to the commodities, ensuring long shelf life.

5.3.1 Objectives of Cooling Foods

Low temperature reduces the rate of chemical and biochemical reactions and retards the activities of microorganisms. A fall in temperature by 10°C reduces the rate of these reactions by one-half. Thus, life of a food could be doubled by merely lowering its temperature by 10°C or quadrupled by reducing 20°C from the ambient temperature. However, this assumption does not hold good as each food material responds to temperature changes differently. A major object of cooling foods is, therefore, to increase their storage life. Holding foods at low temperature also protects their nutritive value and prevents moisture loss through normal metabolic activities and evaporation.

In the industry, cooling of foods may be done for purposes other than preservation. Bread is cooled after baking to facilitate slicing, while beef is cooled for ageing to improve its sensory characteristics. In the production of carbonated beverages, water is cooled before carbonation to increase the solubility of carbon dioxide. Wort is cooled in the brewing industry to precipitate some undesirable components and again after fermentation, the young beer is held at chilling temperature for impregnation of carbon dioxide and precipitation of other insoluble substances.

5.3.2 Pre-treatment of Food for Low Temperature Storage

Food raw materials get contaminated from different sources when they are gathered, harvested or slaughtered. Some contaminants such as microorganisms can be troublesome even under very ideal handling conditions. Food meant for cold storage is prepared according to the requirements for each particular commodity. Beef carcasses are washed, dewatered and then stacked in the chambers that are usually equipped with ultraviolet lamps. Eggs may be dipped in suitable mineral oil and then brought inside the cold store. Fruits are sorted for over-ripe or under-ripe ones, while vegetables are washed, drained and then stored.

Quite often the microbial load of fresh food destined for cold storage is reduced by washing, heat treatment, use of chemicals or irradiation. Lemons, papaya or nectarines are immersed in hot water at a temperature of 46 to 54°C for one to four minutes to pasteurize. Some fruits and vegetables such as cucumbers and root crops are waxed to

improve their appearance and keeping qualities. Shell eggs are usually dipped in light mineral oil 12 to 24 hours after laying—the treatment retards dehydration as well as loss of carbon dioxide and maintains quality of the fresh eggs.

Chemicals are very frequently employed in the treatment of food materials prior to cold storage. Chlorine, acetates, ozone, sulphur dioxide and methyl bromide are commonly used to treat fruits and occasionally vegetables to prevent the growth of microorganisms. Ripening of plantains is retarded by application of purafil, while mangoes are treated with 2, 4, 5–trichlorophenoxy acetic acid for the same purpose. Sprouting in such commodities as onions, potatoes and carrots is prevented by the application of phenyl carbamates, maleic hydrazide or vapours of nonyl alcohol. Ethylene gas is often used as a colour modifier to degreen citrus fruits.

Irradiation has also been very helpful in cold storage of many commodities. Quite often chilled meat is irradiated to destroy the surface microflora and parasites. Primarily, irradiation is used to sterilize the chambers that are now a days equipped with ultraviolet lamps, especially in rooms for storage of meat and cheese. Irradiation of the atmosphere also helps when higher relative humidity and increased storage temperatures are preferred.

5.3.3 Cold Storage Procedure

At home fresh commodities like onions, garlic, ginger, potatoes, sweet potatoes and others are stored in a cool corner of the house for quite some time. Meat, fish, eggs and other perishable commodities are kept in the refrigerator, if not utilized immediately. With storage at lower than ambient temperature, the shelf life of the food materials is considerably extended. Table 5.1 shows the useful storage life of some foods of plant and animal origin at different temperatures.

The refrigerator is general-purpose equipment in which only temperature is controlled and maintained at 4° to 10°C in the refrigerator cabinet. This temperature range is useful in prolonging the shelf life of several raw and prepared foods for a few days only. Fresh fruits and vegetables meant for storage in the refrigerator should be washed to remove the contaminants. It is a common notion among housewives that washed fruits and vegetables do not keep well when stored in the refrigerator. This is because these have not been dewatered. It is essential that extra water from the their surface be removed before these are placed in the refrigerator.

Table 5.1 Generalized average useful storage life of animal and plant foods at different temperatures.

Food	Generalized average useful storage life, in days, at		
	0°C (32°F)	22°C (72°F)	38°C (100°F)
Animal flesh	6 – 10	1	Less than 1
Fish	2 – 7	1	Less than 1
Poultry	5 – 18	1	Less than 1
Dry meat and fish	1000 and more	350 and more	100 and more
Fruits	2 – 180	1 – 20	1 – 7
Dry fruits	1000 and more	350 and more	100 and more
Leafy vegetables	3 – 20	1 – 7	1 – 3
Root crops	90 – 300	70 – 50	2 – 20
Dry seeds	1000 and more	350 and more	100 and more

In practice, the food processor does not take any chances with his commodities. The food is stored under controlled conditions, which guarantee extension in the shelf life. Large capacity cold storages are employed for preserving fresh food raw materials such as fruits, vegetables and tubers.

5.3.4 Factors affecting cold storage of foods

The physiological phenomenon in plant and animal tissues is required to be slowed down to prevent metabolic changes and increase the shelf life. All plant materials respire even after harvesting. The rate varies from one material to another. During storage of fruits and vegetables, oxygen is taken up and carbon dioxide and water are evolved. Respiration in plant materials also results in heat generation and loss in the quality of the product. Animal tissues undergo anaerobic respiration, converting glycogen into glucose and finally to lactic acid. The energy produced during this process eventually gets dissipated as heat, while the lactic acid causes a fall in the pH of meat from above 7.0 to as low as 5.1. All respiration in meat ceases after a post-mortem period of one to 36 hours due to non-replenishment of glycogen or glucose. The refrigeration requirements of plant and animal foods are dependent on several factors. These are temperature relative humidity, composition of storage atmosphere and ventilation.

5.3.4.1. Temperature

The choice of temperature for refrigeration storage of foods depends primarily on the nature of food, estimated desired period of storage, composition of the storage atmosphere and pre-treatment of the raw material. The metabolic activities in some plant materials are very high that result in the production of heat during storage. For example, one ton of green beans, sweet corn, okra or green peas stored for 24 hours at 4.5 °C generate over 252 kilocalories (1,000 British Thermal Units, BTU) of heat. Under similar conditions, over 504 to 1260 kilocalories (2,000 to 5,000 BTU) of heat are generated when the same quantity of carrots or potatoes are stored. Most fruits are slow in respiration and thus release less heat during storage. Grapefruits, lemons oranges, cabbage, onions and tomatoes yield below 504 kilocalories (2,000 BTU) of heat under the same conditions and time.

Since the rate of metabolic activities of each food varies, so does the storage-life expectancy under any specific situation. Depending upon other conditions, some animal tissues, firm, ripe fruits and vegetables may be stored at optimum parameters of chilling temperature and relative humidity for a period of less than two weeks. In an atmosphere containing normal amounts of oxygen and carbon dioxide, beef, mutton, poultry, fish, lemons, nectarines, cabbage, carrots, green peas and spinach may be kept at just above freezing temperature for maximum storage life. Oranges, pineapples and potatoes will best be stored at 2 to 7°C. Bananas, grapefruits, lemons, limes, mangoes, tomatoes, green beans cucumbers, and sweet potatoes are kept at a temperature between 7 to 13°C for maximum life. Green lemons, oranges, cabbage, carrots, potatoes, sweet potatoes and eggs may be stored for over three months at optimum conditions of temperature and relative humidity.

Good insulation is essential to have adequate and uniform temperature inside the chamber throughout the storage period. The insulating material should normally be non-toxic, strong and with low heat conducting properties. Another factor that affects the temperature of cold storage chambers is the temperature difference between refrigeration coils and the storage atmosphere—smaller temperature difference is preferable over a large one, since the latter promotes vapour condensation on cooling coils. Proper air circulation equipment maintains a uniform temperature in cold stores. The specifications of the equipment have to coincide with cooling requirements of the food material.

5.3.4.2 Relative humidity

Control over relative humidity in the storage chamber is vital for extended storage. Too high relative humidity, above the optimum level, encourages microbial growth. Moulds grow in a relative humidity of 85 to 90 percent, yeasts require 90 to 92% and bacterial growth occurs on the food surface at near saturation. Relative humidity below the optimum results in moisture loss, causing wilting in fruits and vegetables or damage to the appearance of animal tissues, thereby incurring economic losses. In many vegetables, a decrease of 3 to 6% moisture will result in a marked loss in quality.

The optimum relative humidity for a particular raw material depends upon the storage temperature. In case of meat, the recommended relative humidity at 0°C is 92%, at 2.2°C 88% and 75% at 4.4°C. Thus, whenever temperature for storage is specified for a particular material, the relative humidity has also to be stated.

5.3.4.3 Composition of the storage atmosphere

In cold storage chambers, an atmosphere containing higher percentage of carbon dioxide and lower oxygen content than are found in air, is maintained to suppress the normal physiological processes in plant materials. Carbon dioxide content of above 10% significantly retards microbial growth on the food surface. Similarly, reducing oxygen concentration from the normal 21% to 10% or lower decreases the rate of respiration. The problem in manipulating the gas atmosphere lies in the difficulty of control. The storage process known as `Controlled Atmosphere Storage' or `CA storage' has technically solved this. In CA storage, machines including scrubbers control the amount of different gases in sealed and insulated storage atmosphere. Ozone may also be used where higher relative humidity is employed, since it helps in the control of microorganisms. Eggs, for example, keep as well in a relative humidity of 90% in the presence of 1.5 ppm of ozone as in 85% in its absence.

5.3.4.4 Ventilation

Ventilation in cold storage chambers is important to prevent the development of stale odours and flavours and remove them from the atmosphere. This is also helpful in maintaining a uniform temperature and relative humidity. In case adequate ventilation or air circulation is not provided, then food in local areas of high humidity may undergo microbial decomposition. This would also prevent maintenance of uniform product composition in the storage atmosphere.

5.4 USE OF BELOW FREEZING TEMPERATURE

The rate of chemical reactions, activities of enzymes and microorganisms are retarded at cold storage or above freezing temperature. However, at below the freezing point of water most spoilage agents are completely inactivated. Chemical reactions proceed at a very slow rate. The human pathogens do not thrive below 3.3°C, while normal food spoilage organisms will not grow below –9.4°C. Some enzymes retain their activity at even –77°C, although the rate of enzyme activity is considerably reduced.

In freezer storage, length of storage and holding temperature are critical in determining the life of frozen foods. Since enzymes are inactivated by blanching or chemical treatment before freezing and most food spoilage organisms will not grow below –9.4°C, therefore, temperatures somewhere below this limit are normally selected for frozen food storage. This provides enough safeguards against any possible temperature rise. Considering the factors involved in food freezing including enzymatic and non-enzymatic reactions, microbiological changes and the cost of freezing and freezer storage, it has been found that freezing of foods to an internal temperature of –18°C and storage at this or lower temperature would be optimal for the maximum life of most products. However, use of temperature as low as –30°C for storage is not uncommon in commerce.

5.4.1 Methods of Food Freezing

Basically there are four methods by which foods are frozen commercially. These are: -

a. Freezing in air – Still air sharp freezing, blast freezing, and fluidized bed freezing.

b. Indirect contact freezing – Single plate freezer, double plate freezer, pressure plate freezer, and slush freezer.

c. Immersion freezing – Heat exchange fluid, compressed gas, and refrigerant spray.

d. Cryogenic freezing.

5.4.1.1 Freezing in air

This is the oldest and the cheapest method. A domestic freezer is a typical example. The food to be frozen should be prepared (washed, peeled, inedible portions removed, cut) and packed in small consumer packs. Meat, poultry and vegetables are often frozen at home. Meat and poultry are cut into small pieces, washed, drained and packed in polythene bags. Vegetables are normally blanched, cooled, drained and then packed. These packets should not be over 1 kg in weight. Efforts should be made to remove as much air as possible from the packages. These should spread in the freezer for quick freezing and not stacked one over the other. Once completely frozen, the packets may be stacked.

In the commercial freezers, food is placed in an insulated chamber on trolleys (Fig. 5.2) or conveyer belt (Fig. 5.3). It is frozen by passing cold air at a specific velocity and direction. The temperature used in still air sharp freezer ranges between –23°C and –29°C. In air blast freezers, it varies from –29 to –46°C. The air velocity in the still air freezing is negligible, while in the blast freezers it may be 15 meters per second. In case of fluidized bed freezing, cold air is passed through the food particles.

Except for the still air sharp freezers, all types using air as the freezing medium may be tailored for batch, or continuous operations and are normally referred to as fast freezing methods.

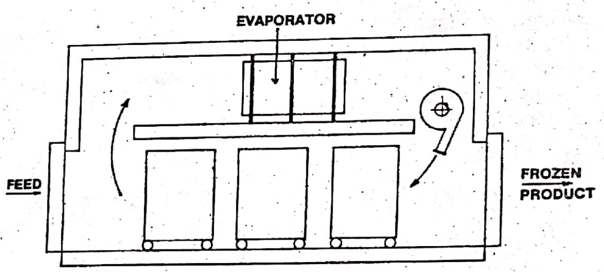

Fig. 5.2 Continuous batch air freezer with counter-flow air circulation

5.4.1.2 Indirect contact freezing

In the indirect contact freezers, the freezing medium cools a surface (plates or walls) with which food comes in direct contact. As a results of the heat exchange, it is frozen. Liquid foods and purees are pumped in-between the cold walls of a heat exchanger and frozen to the slush condition. The efficiency of indirect freezers depends upon the extent of contact between the cold surface (plates) and the food.

5.4.1.3 Immersion freezing

In this type, packaged or unpackaged food material is directly immersed in the freezing medium or the medium is sprayed on it. This method is very efficient since there is intimate contact between food or

package and the freezing medium. This minimizes the resistance to heat transfer. However, since food items come directly in contact with the medium, only non-toxic substances, which would not impart undesirable odour, taste or colour to the product, can be employed as freezing media. The common media used for the purpose include solutions of sugars, sodium chloride and glycerol. A sugar solution containing 62% sucrose or a brine containing 23% sodium chloride will be sufficient to lower the temperature to –21°C. Glycerol-water mixture can be used to obtain a much lower temperature, e.g., with 67 per cent glycerol solution in water, –47°C can be attained.

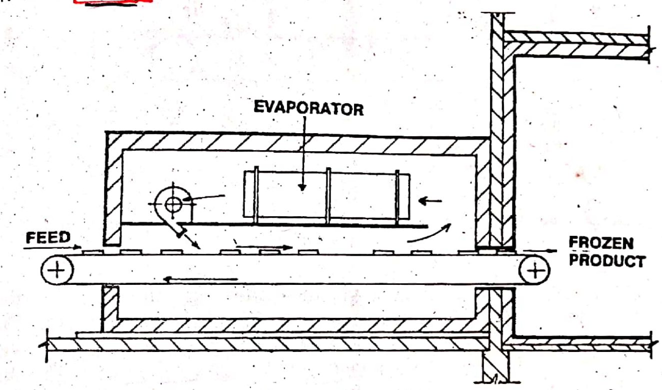

Fig. 5.3 Continuous belt air freezer with concurrent air circulation.

5.4.1.4 Cryogenic freezing

This is similar to immersion freezing. Liquefied gases of extremely low boiling point are employed and the refrigerant itself serves as the freezing medium. Presently liquid carbon dioxide and liquid nitrogen that have boiling points of –79°C and –196°C, respectively are used. The food commodity is immersed in or sprayed by the liquid gas and is frozen in a very short time (Fig. 5.4). Liquid nitrogen is preferred over liquid carbon dioxide because of its lower boiling point. The food is usually frozen to –46°C or above. In most fruits, vegetables, meat and fish, the freezing process may require from 1 to 3 minutes. Some fruits and vegetables, however, show physical quality defects when frozen with liquefied nitrogen gas. For cryogenic freezing, liquefied gases under pressure are more efficient than plain cold gas at the same temperature on account of the extra cooling capacity provided by the latent heat of vaporization. The method is more suitable for products of small size where freezing is completed in a very short time.

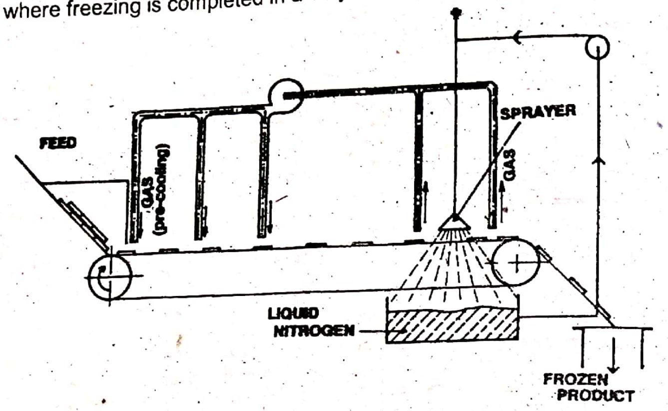

Fig. 5.4 Schematic representation of a cryogenic freezing unit using liquid nitrogen

5.4.2 Effect of Freezing on Foods

When foods are subject to below freezing temperatures, the moisture freezes and turns into ice crystals. The size of crystals may be small (in quick freezing) or large (in slow freezing) depending upon the rate of freezing. Since water expands on freezing by almost 9%, the frozen foods also increase in volume. During storage of frozen foods, ice crystals can grow owing to fluctuations in temperature, thus resulting in physical damage to the food material due to the formation of larger ice crystals.

During freezing operation all moisture present in the foodstuff does not instantaneously change into ice. It first cools to a temperature below the freezing point (super cooling) and then starts crystallizing. As the temperature is lowered, more water is crystallized. The remaining moisture in the food with the soluble solids forms a concentrated solution with a much lower freezing point. A stage is reached when no more water from the solution can be frozen independent of the dissolved solutes and the solution may freeze en masse. Such a solution from which water cannot be crystallized is known as 'eutectic mixture'. It is the last to freeze in a food material and first to thaw when freezing operation is reversed (Fig. 5.5). Freezing ties up most of the moisture in solid form as ice and whatever remains in the foodstuff becomes very concentrated

with dissolved solids. Consequently, moisture is made unavailable to the microorganisms and with combined action of low temperature, shelf life of the food is increased. The eutectic mixture, if still in the liquid state, may ooze out from the package during storage.

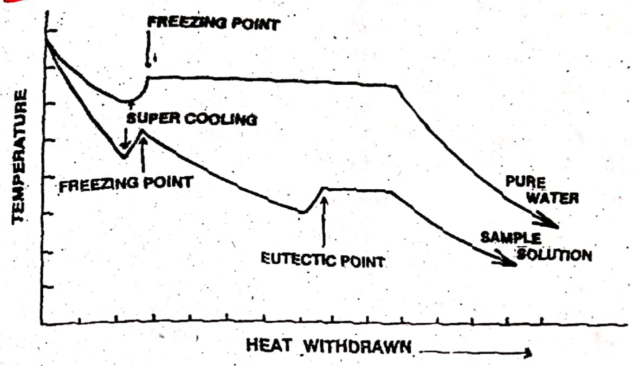

Fig 5.5 Freezing curves for pure water and a simple solution showing the effect of lowering temperature on water and solutions

Very low temperature and moisture immobilization encountered in freezing retard or terminate chemical and enzymatic reactions. Normally the enzymes are inactivated before freezing by heat or chemical treatment. Hence, there are no active enzymes or enzyme activity is drastically subdued. Similarly, ordinary chemical reactions are very much slowed down. However, on prolonged storage, flesh foods such as meat, poultry and fish may become irreversibly dehydrated (freeze burn) as a result of chemical changes in animal proteins. When myoglobin is oxidized, the red pigment on the surface of meat is turned to brown metmyoglobin. Sometimes fats are either oxidized or hydrolyzed.

5.4.3 Storage Life of Frozen Foods

The period, for which a food commodity can be safely kept in a frozen state without appreciable loss in quality, depends upon its nature, its processing, and packaging as well as storage temperature. Though microbial activity ceases practically at –18°C, yet some enzymes still remain active at this temperature. Some chemical reactions also occur at temperatures far below freezing. Therefore, while subfreezing temperature may check the activities of microorganisms, enzyme-catalyzed reactions and other chemical changes still proceed but at a considerably slower pace. Each food commodity behaves differently during freezer storage; hence the period it can stay in such storage facilities will vary depending upon the factors enumerated above.

Heated canned orange juice can stay for up to 27 months at –18°C, while the same juice has a shelf-life of 10 months at –12°C and only 4 months at –6.7°C. Green beans and green peas can be kept for 11 to 12 months at –10°C and only 3 and 1 month at –12°C and –6.7°C, respectively. Raw chicken has a shelf life of 27 months at –18°C; 15.5 and less than 8 months at –12°C and –6.7°C respectively. Similarly, the life of all foods is much lower (almost half) at –6.7°C than at –12°C.

5.4.4 Effect of Thawing on the Quality of Frozen Foods

During freezer storage, intermittent fluctuation in temperature results in greater damage to food than either the freezing operation or storage. A fluctuation of 3°C in freezer storage temperature below –18°C, can cause considerable damage to the food. During thawing, foods are subject to damage by physical, chemical, and microbiological means. When food thaws, ice crystals melt and change to liquid state; on refreezing these once again turn into ice crystals but larger in size and eventually cause physical damage to the product. The chemical reactions and enzyme activity would be faster at higher temperature.

As some microorganisms are not killed before and during freezing or subsequent frozen storage, these will become active when the food is thawed. Although microbiological changes in foods are negligible as a result of temperature fluctuations, yet this aspect cannot be ignored. It is only on rare occasions that commercial freezers breakdown without notice. Therefore complete thawing in operating freezers is uncommon.

Frozen foods (except ice cream and similar products) must be defrosted or thawed prior to consumption. The time required for thawing operation is very crucial to the quality of food material. The longer the food takes to thaw, the greater will be the damage caused by proliferation of microorganisms that have survived freezing and storage. For example, when frozen whole egg meat is thawed under a dielectric heat source, the time required is 15 minutes and negligible increase in microbial count occurs. The same product when thawed in running water at 21°C requires 12 hours, and the microbial population increases to about 300% of the original count. In case air at 21°C is employed for thawing, 36 hours are required and the microbial population increases by 750 per cent during this period.

5.4.5 Effect of Freezing on Microorganisms

Most microorganisms survive freezing temperature for quite some time. Since all moisture is not frozen at 0°C or slightly lower, some microorganisms may still find conditions suitable for their growth at as low as –5°C on meats, –10°C on ice cream, –11°C on fish and –12°C on peas. Yeasts have been reported to grow at –5°C on meat and –17°C on oysters, while moulds have been found growing at –7.8°C on meats and vegetables.

Subjecting food to below freezing temperature considerably reduces the microbial population, but does not sterilize it. Thus, while a canned food is expected to be sterile or near sterile, a frozen food is never near to that condition. It implies that more care has to be taken in handling a frozen than a heat processed or canned food. However, during freezing quite a substantial percentage of microbial population, between 50 to 80 per cent, is killed depending upon the following factors:

a. **Kind and state of microorganisms** – Generally, bacteria are more resistant to destruction by freezing temperature than yeasts or moulds. Similarly, growth phase of the organism determines the effect of freezing temperature upon viability of the population—young and old cells are easily killed by freezing than mature ones. Vegetative cells in the lag phase are more susceptible than those in other phases of growth and the spores.

b. **Kind of food** – The composition of food invariably affects the susceptibility of microorganisms to freezing temperatures. While sugar, salt, proteins, colloids, fats and other food components may offer protection to microbial cells, high moisture content and low pH will hasten killing of microorganisms.

c. **Freezing and storage temperature** – Very low freezing or storage temperatures are not very lethal to microorganisms. The most critical range for microorganisms is between –1° to –5°C. Foods frozen or held for a long time at this range will have less number of viable cells. Slow freezing causes more damage to microorganisms but the same condition is also detrimental to product quality.

d. **Length of storage** – Longer storage periods are helpful in decreasing the numbers of viable microorganisms in a frozen food.

NOTES

"THE MAN WHO DOES NOT READ GOOD BOOKS HAS NO ADVANTAGE OVER THE MAN WHO CAN'T READ THEM"

chemical
Biochemical
Microbial activities

6

REMOVAL OF MOISTURE

Water is essential for chemical and biochemical reactions and microbial activities in foods. Without available moisture, the spoilage agents would be completely inactive. It is present in practically all foods in varying quantities. Fresh fruits, vegetables, meat and fish that contain high levels, spoil readily. Dry beans and cereal grains have relatively low moisture and can be stored for long periods without spoilage. This knowledge has been utilized for centuries to preserve foods by sun drying.

6.1 ROLE OF WATER IN FOOD

Water plays one or more roles in a food system. It may: -

a. serve as a solvent,

b. participate in chemical and biochemical reactions as principal reactant in processes involving hydrolysis.

c. be product of chemical reactions involving condensation,

d. serve as a modifier of the catalytic activity of other substances in food, e.g., metallic catalysts associated with lipid peroxidation are inactivated by water.

6.2 FORMS OF WATER IN FOOD

Water exists in foods in 5 different forms such as:

a. Free water (e.g., in tomato juice).

b. Droplets of emulsified water (e.g., in butter).

c. Water tied in colloidal gels (e.g. in jellies).
d. A thin layer of adsorbed water (e.g., in powdered milk).
e. Chemically bound water of hydration (e.g., in sugar).

The chemically bound water is extremely difficult to remove during drying, while free and adsorbed water is easy to manipulate. In removal of moisture, the free and absorbed moisture is removed by suitable means. In this manner the water becomes unavailable for the chemical and biochemical reactions, as well as the activities of enzymes and microorganisms. Moisture from the foods may be removed by any of the following methods: -

a. Sun-drying
b. Dehydration
c. Evaporation / Concentration
d. Freeze-drying
e. Dehydro-freezing

6.3 ADVANTAGES OF DRIED FOODS

Dried foods, preserved by the removal of moisture, are less expensive than most foods preserved by other methods. These are concentrated sources of nutrients and are high in total solids. The dehydrated foods, because of reduced weight, are less costly to transport. They also require less storage space. While sun drying is restricted to countries with plenty of sunshine, dehydration can be practiced in any part of the world under any climatic conditions.

6.4 SUN-DRYING

Sun drying refers to removal of moisture from foods by exposing them to the direct energy from the sun's rays. Many food grains such as cereals and pulses become naturally dried in the field by solar energy and are protected from autolysis and microbial attack. Their moisture content usually varies from 8 - 16% and water activity is normally 0.75 or below. In addition to these naturally preserved foods, other perishable commodities are sun-dried in order to prolong their shelf life. In tropical and sub-tropical regions with abundance of sunshine, several fruits and vegetables are sun-dried. Examples are sun drying of grapes in Afghanistan, Greece and United States to produce raisins and the drying of dates in Saudi Arabia, Iraq, Tunisia, Egypt and Algeria. Guava, tomato, pears and peaches are also sun-dried in several parts of the world. In Pakistan fruits including figs, plums, grapes, dates and apricots are sun dried.

6.4.1 Equipment

Equipment required for sun drying varies according to the product to be dried, local conditions and the scale of production. However, any one engaged in sun drying of fruits and vegetables would need wooden boxes of appropriate size for collection of raw material from the field. In the preparation shed, cutting tables, cutting knives, peeling knives, aprons, etc. are required. The prepared raw material needs to be placed in suitable sized trays that are usually constructed of wood. Blanchers or sulphuring equipment may be needed. After drying, the raw material is brought to the sweating chamber. Packaging equipment is required to pack the dried product in suitable sized moisture-proof containers.

6.4.2 Procedure

The raw material for sun drying needs preparatory treatments similar to those required for preservation by canning, freezing or other techniques. The fruit may be washed, peeled, cut and then blanched or sulphured. It is left in the open sun in trays and turned occasionally until dried to the desired degree. The dried fruits are then sorted and stacked in boxes or bins for moisture equilibration—a process know as sweating. It may now be stored in insect- and rodent-proof storage rooms.

6.4.3 Precautions

Since the raw material for sun drying is directly exposed to the atmosphere, there is danger of contamination from natural sources. Microorganisms floating in the atmosphere may settle on the product. Birds and animals should not be allowed in and around the vicinity of the drying yard. Cleanliness in all operations is absolutely essential. Great care should be taken during the drying process to prevent contamination. All equipment should be properly sanitized. Waste fruit should not be dumped near the drying area and where this is not possible, it should be treated in a pit with lime chloride to prevent its decay and multiplication of microorganisms and flying insects, especially flies.

Dried products are subject to attack by insects and rodents. These should be protected by providing insect-proof room for storage. Occasionally this room is fumigated with suitable gas to kill insect pests. Since dried foods usually deteriorate at room temperature and lose both colour and flavour, it is preferable to store them at lower temperatures, especially if stored in bulk bins. Most processors prefer to keep their products in cold stores at a temperature of 0 – 4°C. This also prevents damage by insects and rodents, apart from protecting product quality.

6.5 DEHYDRATION

Dehydration is an operation in which water content of food is substantially lowered under controlled conditions of temperature, humidity and airflow. Under these conditions, high quality products are obtained that retain their natural characteristics upon rehydration or reconstitution. Foods that have been successfully preserved by dehydration include fruits, vegetables, milk, eggs, fish, cake mixes, soup mixes and others. The raw material determines the handling techniques and type of equipment needed for dehydration.

6.5.1 Drying atmosphere

In the removal of moisture from natural foodstuffs, heat energy is supplied to the food. Water, which evaporates, is removed from the vicinity of the raw material. Foods may be dried in (a) hot air, (b) superheated steam, (c) vacuum, (d) heated inert gas, or (e) by direct application of energy from a radiant microwave or dielectric source. However, air is the most common medium for removal of moisture from foods for several reasons: dehydrators using air are less to construct. They are more convenient to install and operate. By using air as a drying medium, overheating, discolouration and scorching of the product is greatly avoided. Air also permits gradual drying of foods, thereby avoiding loss of juice by dripping.

Primarily, there are three major roles of air in dehydration. It conveys heat energy to food, vaporizes moisture from the commodity and transfers the liberated moisture to the atmosphere outside. A larger volume of air is required to vaporize moisture from the food than to transport it out of the drying atmosphere. The volume of air required for drying is calculated from the initial temperature of air entering the drier, volume of moisture required to be evaporated, time in which the operation has to be completed and temperature of air leaving the dehydrator. Other factors connected with this calculation are the heat losses through leakage and heat required to raise the temperature of trays and walls of the dehydrator.

6.5.2 Factors affecting evaporation of water from food surface

The rate of moisture evaporation from the free surface of a food material depends upon the nature of food material, the particle size, the bed depth (in case of pieces placed on a surface), humidity, temperature and the velocity of air.

All food raw materials do not react in the same manner to changes in atmospheric conditions. Since moisture travels out of the food from inside, larger particles take longer time to dry than the smaller ones. Thus, while it may take a few hours for okra pieces to dry in a tunnel drier, several hours may be required when whole okra is dried under the same conditions. When tissue foods are dried in cabinet or tunnel driers, the depth of raw material on the tray surface will also determine length of the process. Atomization of fluid foods into small particles, as seen in spray drying of milk and instant beverages, cuts the drying time to a matter of seconds.

The relative humidity and velocity of air are other important factors that must be carefully controlled in dehydration processes. Air, high in relative humidity will not accommodate the extra moisture from the food. At low temperature, air is easily saturated with moisture, hence will not be efficient for the purpose. The rate of moisture evaporation from the free surface of food material is directly proportional to the velocity of air, provided other factors remain constant. It has been found that at an air velocity of about 70 meters per minute, drying would be twice as rapid as in still air and at 140 meters per minute, it would be three times as fast.

Food materials are living units and moisture has to travel out from inside the pieces. At high temperature, low relative humidity and high velocity of the drying air, the food surface can get dried, while the moisture inside the food is unable to travel towards the outer surface—a situation known as `casehardening'. This results in food being dry outside and wet inside. Therefore, air velocity is usually regulated in commercial dehydrators between 91 and 304 meters per minute. Air velocity beyond this range is uneconomical. Part of the spent air may be recirculated to avoid casehardening and economize on heat expenditure.

6.5.3 Types of Dehydrators

Depending upon the mechanism of transferring heat energy from the heat exchanger to the food, all dehydrators can be grouped into one of the following categories: -

1. Hot air driers
   a. Natural draft driers – kiln, cabinet, tower and Oregon tunnel driers.
   b. Forced draft driers – Tunnel (concurrent, counter-current, centre-exhaust tunnel driers, cross flow tunnel drier), conveyer drier, fluidized bed drier, spray drier.
2. Drying by contact with heated surface – Drum drier, vacuum shelf drier
3. Drying by application of energy from a radiating microwave or dielectric source – Radiant heating drier, continuous infra-red drier, microwave and dielectric heating drier
4. Special drying techniques – Puff drying, foam mat drying,

6.5.3.1 Hot air driers

a. Natural Draft Driers

The natural draft driers, in general, consist of a furnace room or other heating arrangement (steam pipes, electric heaters), surmounted by a drying chamber. The air is heated by contact with the radiating pipes and enters the drying chamber by natural convection currents. These driers are inexpensive to build and have low fuel efficiency. Most natural draft driers are now equipped with fans which have considerably increased their efficiency.

The kiln drier is one of the oldest type and is employed in the drying of hops (flowers of hop plant used in brewing to impart bitter taste), cacao and apples. It is unsuitable for drying soft fruits. The drier consists of an upper storey that houses the drying floor, and a ground floor that accommodates the heating system. At the top of the upper floor is an exit for escape of the spent air.

In the tower drier, the drying chamber can accommodate several drying trays stacked one over another in the form of a tower. The heating system is like the kiln drier. The cabinet drier is similar to tower drier except that steam coils placed below the trays furnish heat. In this type, temperature of the air can be conveniently regulated and drying made more rapid. The modern types of cabinet driers consist of compartments that hold several trays over or through which hot air is blown by special fans (Fig. 6.1).

The Oregon tunnel drier consists of a series of parallel, sloping narrow chambers above the furnace room. The hot air enters at the lower end of each tunnel through an opening or throat, while trays of food material (normally fruits) enter the drier at the upper or cool end and progress towards the lower or warm end. The dry fruit is removed from the lower end of each tunnel. This type is very suitable for drying plums to produce prunes.

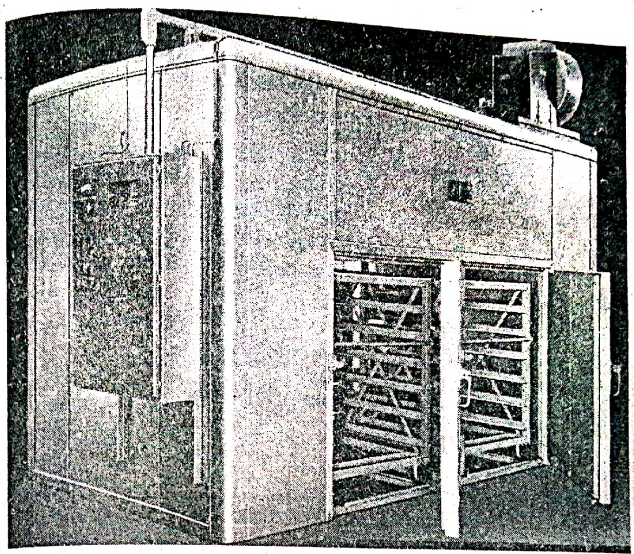

Fig 6.1 A cabinet drier

b. Forced Draft Dehydrators

The forced draft dehydrators offer more efficient energy utilization and control over the product. In principle, all forced draft dehydrators consist of a heating chamber, which may be heated by any conventional means, the drying chamber where food may be placed and a system to circulate air through the foodstuff. Normally these driers have arrangement for re-circulation of air that increases fuel efficiency and prevents casehardening.

The tunnel drier consists of a chamber in the form of a tunnel, which is longer than it is wide. Depending upon the direction of the movement of air over the product, a tunnel drier may be concurrent when air and raw material move in the same direction or counter-current (Fig.

6.2) if these move in opposite direction to each other. In some driers, air may enter from both sides of the tunnel and is let out from the middle. Such a drier is called centre-exhaust tunnel drier (Fig. 6.2) and has the advantage of producing a better quality product than the other driers. In another version, called cross flow drier, the air flows across the direction of food.

In tunnel driers, food is normally placed in trays that are stacked on trolleys or trucks and these move the length of the tunnel. Heating of air is done either by steam coils, electrically heated grids or hot air furnace. The air supply is maintained by using disc, multivane, airplane propeller, axial or paddle wheel types of fans.

The conveyer drier such as continuous draper or belt drier is similar to the tunnel driers in construction, except that the raw material moves on endless conveyers rather than trucks or trolleys. This type is suitable for drying vegetables, starch, etc. Air is usually blown across the product in a con-or counter-current design.

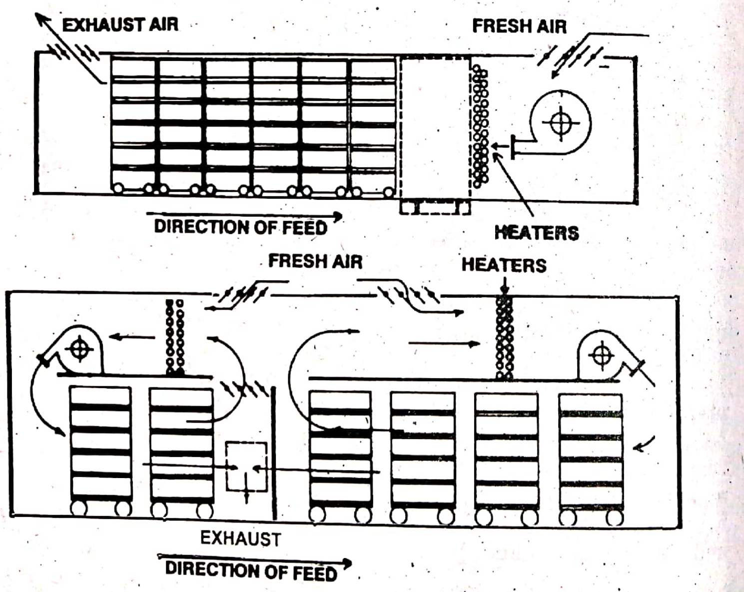

Fig. 6.3 Schematic representation of typical counter current (above) and centre-exhaust (below) tunnel driers.

Fluidized bed drier is used for dehydration of particulate or diced materials, e.g., grains, cacao, coffee, onions, diced vegetables, as well as for drying granulated materials such as sugar and salt. Hot air passes from the bed through a porous plate at a pressure that is enough to float the food particles in suspension. The supply of air is so regulated at different points in the bed that, in addition to removing moisture and transferring it to the outside atmosphere, it also conveys the food particles and discharges them at the exit end of the drier. The pressure of hot air through the food is just enough to suspend the particles giving an impression of gentle boiling motion.

Spray driers are employed for liquid and other foods (milk, eggs, instant coffee etc.) of low viscosity that can be atomized. In a typical spray drier, liquid food is atomized into a drying chamber through a fine nozzle. Hot air is passed into the drying chamber and the food material dries instantly. Since some powdered material may be lost with exhaust air, a recovery system (cyclone system) is usually attached to the air exhaust in which the suspended powdered particles are recovered and spent air is allowed to escape or recirculate.

6.5.3.2 Drying by contact with heated surface

Some foods such as milk, soup mixes, baby foods, mashed potato, and others that are either liquid or can form slurry are also dried by exposing them directly to hot surface. The drum drier is a good example in this group. It essentially consists of one or more hollow metallic cylinders called the drum that is heated internally by steam, or other heating medium. The cylinder revolves on a horizontal axis. As the drum revolves, it collects a thin film of the liquid or slurry at a certain point. By the time it goes around by about 180 – 270°, the film is dried and a special scraping assembly removes the dried film and drops it onto a conveyor. Another film of wet material then coats the drum for the next round of drying. Conventional drum driers are economical to use, but heat sensitive products may be adversely scorched. Usually drum driers are classified according to the number of drums in one unit, e.g., single, double or twin drum systems.

In vacuum shelf drier, food is placed between two plates in a system where vacuum can be created. The foods are dehydrated under vacuum at low temperature. The procedure is comparatively expensive, hence is used for highly priced and heat sensitive foods.

0.8–400nm
915 → 2450

6.5.3.3 **Drying by application of energy from radiating microwave or dielectric sources**

Several types of radiations from the electromagnetic spectrum are capable of producing heat in food materials and thus evaporating or boiling water from them (see Chapter 9). The infrared radiations are highly absorbed by foods resulting in heat generation. The radiations commonly employed have a wavelength of 0.8 to 400 nm. These are used primarily for surface heating, hence find applications in dehydration of fruits vegetables, grains and tea, as well as in baking, freeze-drying and roasting of cacao beans and nut kernels.

Some waves, especially at frequencies of 915 MHz (wavelength 3.28×108 nm, dielectric heating) and 2450 MHz (wavelength 1.22×108 nm, microwave heating), are used in the food industry for drying and other purposes. When food materials absorb waves at these frequencies, heat energy is generated. In dielectric heating, food material is heated by keeping it between parallel electrodes, while in the microwave heating, it is placed in a resonance cavity. In microwave heating, microwaves produced by a magnetron tube when absorbed by the food, generate considerable heat through a series of rapidly alternating currents, which produce friction within the material. The food gets instantaneously, heated from within. The dielectric and microwave heating have found applications in quite a few situations in the food industry such as concentration and drying, besides baking, cooking, blanching, pasteurization and sterilization. These are also becoming popular for preliminary or finishing steps in drying potato chips, cooking chicken pieces and baking crackers.

6.5.3.4 **Special drying techniques**

Special drying techniques are applied to produce certain effects in foods that are not possible with the normal methods of dehydration. Puff drying is employed to increase the porosity of food particles to give them a spongy look. Such products are easier to reconstitute and have a better texture than those dried by the usual techniques. Production of potato puffs represents a good example of this technique in which the escaping steam tends to puff the product.

Foam mat drying has a similar object, i.e., producing a product with larger volume and spongy texture. In this case the raw material may be whipped, e.g., egg white. In concentrated citrus juices, fruit purees and tomato paste, an edible whipping agent is added prior to whipping.

6.5'

Stable foams are then cast in thin layers onto trays or belts and are dried by any appropriate system.

6.6 EVAPORATION AND CONCENTRATION

Evaporating some moisture, thereby concentrating the soluble solids, can lower the water activity of a food material. Tomato paste is a common example where evaporation is a part of the preservation technique. Initially tomato juice contains about 6% solids that are concentrated by evaporation to about 32%. Evaporation helps to reduce the weight of food materials, thereby lowering packaging and transportation costs. Normally water activity of most evaporated foods is still high enough to encourage growth of spoilage microorganisms and, therefore, such foods require further processing. Most are given heat treatment milder than would be the case for their unevaporated counterparts or may be concentrated by the addition of soluble constituents to further decrease their water activity.

Common salt is obtained by concentration from seawater, through evaporation in artificial lagoons. In the sugar industry, sugar cane or sugar beet juice is concentrated by evaporation from approximately 15% sugar content to saturation. Sugar syrups are prepared to 70°Brix. In the production of jams, jellies and other such foods, sugar is added to fruit pulp and part of the moisture is removed by evaporation in open type or vacuum pans. Microorganisms normally do not thrive in foods that are high in sugar, especially above 65%. Hence, jams and similar products packed in hermetically sealed containers must contain at least 65% dissolved solids. If the product is packed in non-hermetically sealed containers, a minimum of 68% dissolved solids is usually desirable.

However, for concentration of products like fruit juices that must retain their very delicate chemical, textural and sensory characteristics, special types of evaporators are employed. These could be the natural circulation evaporators that include:

a. open pan type,
b. horizontal or vertical short tube type,
c. natural circulation type, (with external calandria),
d. forced circulation evaporator,
e. long tube evaporators, (climbing film, falling film and th climbing-falling film models),
f. plate type,

g. expanding flow evaporator
h. centrifugal evaporator
i. low temperature evaporator or
j. the bubbling type evaporator.

Each of these has its own advantages and disadvantages and is suitable for concentration of specific products.

Food may also be concentrated without any evaporation taking place. Butter contains about 80% fat. It is concentrated milk fat produced from milk which initially contains between 3.2 to 6.5% fat. The fat in milk is first concentrated into cream through centrifugation and then the cream is further concentrated by (churning) a process in which fat globules are removed in the form of emulsion and the liquid or whey drained out. Similarly, in the manufacture of cornstarch, centrifuges are employed to dewater the starch and no evaporation is involved.

6.7 FREEZE-DRYING

In response to demand by consumers for preserved foods, which show minimal quality differences from the fresh, food technologists have provided various innovative solutions. Freeze-drying is one processing technique that does minimal harm to product quality. Foods that are freeze-dried are light, porous in structure and when reconstituted, exhibit most good characteristics of the fresh commodity. Additionally, freeze-dried products retain shape and size of the original raw material.

Freeze-drying involves freezing of food material followed by removal of moisture by sublimation, i.e., evaporation of moisture from the solid state to vapour state without first changing into liquid. The sublimation process is carried out at low vacuum (usually at 0.1 – 2 mm Hg). The product is often finished in an ordinary drier since some moisture may remain in the food. Some disadvantages of freeze-drying include the possible damage to raw material cell structure when freezing is poorly executed. Moreover, the product is brittle and, therefore, susceptible to mechanical damage. Also, freeze-drying process is very expensive as compared with other conventional drying techniques. This method is suitable for coffee, fruit juices, whole shrimps, chicken dices, etc.

6.8 DEHYDRO-FREEZING

This is a less commonly used method of food preservation. Basically dehydro-freezing involves moisture reduction by any suitable

dehydration technique followed by freezing rest of the moisture present in the food. The freezing ensures further reduction in water activity.

In practice, the process consists of removal of about 50% moisture from the foodstuff and then subjecting this partly dehydrated material to normal freezing operation. In this manner, the bulk of the food is reduced, thereby lowering storage, transportation and handling costs. The product is superior in quality to a purely dehydrated one, as it better retains the flavour and texture.

6.9 INTERMEDIATE MOISTURE FOODS TECHNOLOGY

The available moisture in foods can be bound, making it unavailable for spoilage agents. Such a technique is employed in the production of intermediate moisture foods that have moisture content usually varying from 20 – 50%. The water activity of intermediate moisture foods generally ranges from 0.70 to 0.85, which is low enough to prevent the growth of many spoilage bacteria and yeasts. However, this water activity is relatively high for several spoilage moulds and osmophilic yeasts. The intermediate moisture foods are honey, jams, jellies, confectionery products, sweetened condensed milk, and similar products.

The moisture content in these foods is lower than in fresh commodities but higher than in conventionally dehydrated foods. The available moisture left after binding with chemicals is not high enough to support enzyme and microbial activity. Thus, the food remains semi-moist and can be kept on kitchen or retailer's shelf for long periods. The greatest preservation effect in these products is on account of high concentration of solutes resulting in high osmotic pressure. Additionally, salts, acids and other chemical substances may be used to extend the storage life further. These foods also have simpler packaging requirements and can be packed in inexpensive protective wrappers.

The principle underlying the technology of intermediate moisture foods is that water activity of the material is lowered by partly removing the moisture. This is followed by the addition of such chemicals as common salt, glycerol, sorbitol, sucrose, glucose or others that bind part of the remaining moisture. In these products, microbial growth is further retarded by employing antimicrobial agents, especially antimycotics such as propylene glycol and/or sorbic acid or its potassium salt. The technology of producing intermediate moisture foods could be particularly useful and practicable for developing countries that lack the normal low temperature storage facilities.

NOTES

"A ROOM WITHOUT BOOKS IS LIKE A BODY WITHOUT SOUL"

7

USE OF CHEMICAL ADDITIVES

7.1 DEFINITIONS

7.1.1 Contaminant

Any substance not intentionally added to food, which is present in such food as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food or as a result of environmental contamination. These substances come into foodstuffs accidentally and include grease or mineral oils from processing equipment as well as soil, stones, metallic pieces, plant materials, microorganisms and pesticide residues.

Insecticides are most commonly employed pesticides. Their residues are usual contaminants in foods of plant origin. DDT accumulates in natural food chain. It causes restlessness and increased excitability followed by muscular twitching. Chloradane causes stimulation of central nervous system. Similarly aldrin and dieldrin residues affect the central nervous system. Organophosphates cause headache, giddiness, nervousness, blurred vision, nausea, diarrhea, and other symptoms.

Trace elements like mercury, lead, selenium, tin, cadmium, aluminium, arsenic, fluoride and iodide that contaminate foods have been shown to elicit toxic effects in animals and man. These enter the food through air (automobile emission), or irrigation water containing domestic and industrial wastes.

7.1.2 Food Adulterant

Some substances are added intentionally to foods for the purpose of making more profit. These aid food processor or distributor to cheat or undermine the intelligence of the consumer, and are generally referred to as food adulterants. Food adulterants are used to mask the inferior quality of a product or to increase its quantity, thereby deriving more profit from an equal quantity of unadulterated product. Common examples of food adulteration are the addition of water in honey and whole fluid milk, or removal of cream from milk, or increasing the quantity of *desi* ghee by the addition of vegetable ghee (Table 7.1). Unscrupulous traders have engaged in the art of food adulteration since prehistoric time, and at present practically no food is safe from their clutches. However, legislations are in force in all countries of the world to prevent the exploitation of consumers by food adulterators.

Table 7.1 Common adulterants in some foods.

Food	Adulterant
Baking powder	Citric acid
Black pepper, whole	Dried papaya seeds
Butter	Excess moisture, vegetable fats, animal body fat
Coffee powder	Exhausted coffee, roasted date kernels
Common salt	Sand, water
Flour	Sand, foreign starch, chalk powder, talc
Grains	Stones, sand, grit, mud, weed seeds
Honey	Water, sugar
Margarine	Excess moisture, animal fat
Milk, whole	Water, starch, removal of fat
Sugar	Fine white sand, dirt, semolina
Tea	Exhausted tea leaves, black gram husk
Vegetable oil	Cheap oils, mineral oils

Sources: Awan, J.A. 1979; Jacob, T. 1963.

7.1.3 Chemical Additive

A chemical additive is a substance or a mixture of substances, added intentionally for a technological purpose during manufacture, processing, preparation, treatment, packing, transport or storage. These facilitate to enhance the qualities of the foodstuff. These may help to prevent microbial spoilage, avoid toxin development, reduce nutritional losses and retard aesthetic changes. These substances may improve appearance, colour, flavour, taste and nutritive value or even increase the shelf life of the product. Additionally, these may be functionally important in the development of the specific product.

7.2 FUNCTIONS OF FOOD ADDITIVES

Chemical additives perform numerous functions such as: -

a. Make possible increased agricultural yields through enhancing feed utilization in poultry and livestock.

b. Facilitate handling, distribution and preparation of foodstuffs.

c. Control physical, chemical, and microbiological changes so as to lessen waste, preserve quality and reduce health hazards.

d. Facilitate modification and synthesis of food contents to meet special dietary needs and to offer novel and convenience foods.

e. Improve sensory and nutritive properties.

In food processing, chemical additives perform two broad functions: non-preservative and preservative.

7.3 CHEMICAL ADDITIVES AS NON-PRESERVATIVES

As non-preservatives, several substances are added in foods to improve colour, taste, flavour, nutritional value or functional properties. Table 7.2 provides a summary of such common additives and their functions. Quite often, a single additive may perform more than one function For example, sugar is added in products to provide taste (sweetness), while it also serves as a nutrient (calories) and in foods like jams, as a preservative.

7.3.1 Improve Colour

Many natural substances (e.g. β-carotene, caramel, chlorophyll) and synthetic chemicals (dyes and lakes) are added to improve the colour of foodstuffs. Food-grade permitted colours are used in fruit products (juices, squashes, jams, jellies), carbonated beverages, bakery products (cakes, biscuits) as well as in candies and others. The use of these colouring substances, like all other food additives, must conform to legal requirements. It is quite common to find small food processors using non-food grade colours in Pakistan.

Some chemicals bleach the natural colour of food materials, thereby giving them a superior look. In flour production, for example, benzyl peroxide an oxidizing substance, bleaches out any residual natural yellow colour in freshly milled wheat flour. Similarly, hydrogen peroxide is used to whiten the colour of fresh whole milk for the production of some kinds of cheeses. Sulphur dioxide improves colour of many fruit and vegetable products.

Table 7.2 Non-preservative functions of some chemical additives in foods.

Function	Chemical additives
Acidulants	Acetic, citric, fumaric, lactic, malic, phosphoric, succinic, and tartaric acids, glucono δ-lactone.
Anticaking agents	Aluminium silicate, calcium carbonate, magnesium oxide, calcium phosphate, silicon dioxide.
Antifoaming agents	Dimethyl polysiloxane, silicon dioxide
Colours	Amaranth, annatto, anthocyanins, betanines, carotenoides, caramel, carmine, carmoisine, coal tar dyes, indigo, turmeric, tartarzine.
Emulsifiers	Acetylated monoglycerides, glycerol esters, lecithin, mono- and di-glycerides, dioctyl sodium sulphosuccinate
Firming agents	Aluminium potassium sulphate, aluminium sulphate, calcium gluconate.
Flavour enhancers	Calcium inosinate, gluconates, glutamates (monocalcium and monosodium), glutamic acid, guanylates (Ca and Na).
Meat tenderizers	Bromelin, ficin, papain.
Sweeteners	Glucose, fructose, sucrose, aspartame, cyclamates
Thickening agents, stabilizers	Agar, amylose, carboxymethyl cellulose (CMC), carrageenan, gelatine, guargum, gum Arabic, microcrystalline cellulose, pectin, powdered cellulose, gum tragacanth.

7.3.2 Improve Flavour

Natural flavouring substances include spices, herbs, essential oils and plant extracts. Currently there are over 12,000 different flavouring materials used in foods, making this the largest single group of food additives. A number of food flavouring compounds are extracted from natural raw materials, while still larger numbers are synthesized. Extracted flavours from plant materials in the form of essential oils and oleoresins find application as food flavouring agents. Flavours derived from orange and lime peels are common ingredients in orange and lime-based products.

Synthetic flavours are more commonly added to food materials. Ethyl butyrate is the base in pineapple flavour, methyl anthranilate in grape flavour, isoamyl acetate or amyl acetate in banana flavour, while benzaldehyde is the base material for almond flavour. Synthetic and extracted food flavours are available in powder or liquid form, or as encapsulated dry flavours.

Additionally, some substances called flavour enhancers are added to accentuate the original flavour of the foodstuff. These may not have a flavour of their own, but are efficient in bringing out the natural flavours of foods to which they are added. Monosodium glutamate (MSG) is a common flavour improver employed in meats, gravies, sauce and foods rich in proteins. Its excessive use results in toxicity—a burning sensation in the back of neck spreading to forearms and subdermal comfort.

7.3.3 Improve taste

The basic quality of a foodstuff meant for human consumption is that, in addition to its appearance, it should have a good taste. All foods have a natural taste of their own. However, several additives are employed to improve the taste of foods—sugar, salt, spices and acidulants are common substances that bring the desirable taste. Some synthetic low-caloric sweeteners such as sorbitol and cyclamates are, likewise, are used to impart sweet taste to the products, particularly for the diabetic and obese individuals.

7.3.4 Improve nutrition

Generally natural foods lack a few nutrients or may lose some during processing. Thus, at times, need arises to fortify the foodstuff with suitable nutrients. Examples are addition of vitamins A and D and iron to infant milk recipes, B vitamins, iron and calcium to cereal products, iodine to common salt, vitamin C to fruit products and vitamin A to margarine and other butter substitutes.

7.3.5 Improve functional properties of foods

Fresh and processed foods have characteristic textural properties. At times, it may be necessary to add substances that will favour the attainment of desired characteristics. For example, texture of potatoes, fresh peas and tomatoes softens on canning. Addition of calcium chloride or calcium phosphate provides firmness to the product. Similarly, in salad dressings and mayonnaise production, emulsifiers are help to form homogeneous mixtures of oil and water, the two major components of these and similar products. The emulsifiers such as monoglycerides, diglycerides and phospholipids (e.g., lecithin), help formation of the oil/water emulsion, which is stable. Emulsifiers are also important in the baking industry where they improve the volume, uniformity and fineness of grain in bread and rolls. These favour even distribution of fat in the batter and give stability to the foam structure in baked goods.

Stabilizers and thickeners are important in several manufactured products, such as cake toppings, chocolate milk drinks, jellies, puddings, salad dressings, gravies and others. These substances prevent separation of various ingredients of the mix. Calcium chloride and calcium gluconate are permitted as stabilizers in jams and jellies, pickled cucumbers as well as in canned peas, tomatoes and other products. In evaporated milks, sweetened condensed milks, milk powders and cream, mono-calcium phosphate (monobasic) or tri-potassium citrate are employed. In ice cream stabilizers increase viscosity and prevent formation of large ice crystals. Vegetable gums such as gum tragacanth and gum Arabic, agar, pectin, and gelatine find applications as stabilizers and thickeners in numerous products. Cellulose compounds like methylcellulose and carboxymethyl cellulose (CMC) are used for the same purpose.

Leavening agents are useful in the production of pan bread, light cakes, biscuits, wafers, muffins and many other baked goods. These give the desired textural characteristics to the product. Sodium bicarbonate and baking powders, which contain sodium bicarbonate, an acid, salt and starch, are commonly employed as leavening agents in the baking industry.

In other foods, chemical additives serve one or more of several functions. Moisturizing agents, commonly known as humectants, are

employed to retain moisture in products like-shredded coconut. Anticaking agents are added to table salt, garlic and onion salts and powders, powdered sugar and malted milk powders to prevent caking. Clarifying agents help to improve the filterability, appearance, as well as the quality of food to which they are added. In several manufactured products, chemical additives are used as creaming, glazing, peeling, curing and foaming agents. State food laws regulate the limit as to the use of these substances.

7.4 CHEMICAL ADDITIVES AS PRESERVATIVES

In addition to the use of chemicals for various non-preservative purposes, some are employed to increase the shelf life of food commodities. Among these are anti-ripening agents, sprout inhibitors, anti-microbial agents and anti-oxidants.

7.4.1 Anti-ripening agents

Fruits continue their normal physiological functions even after being detached from the tree and ripen after harvesting. Sometimes during cold storage of such commodities, it is essential to control the ripening process. Chemical compounds such as purafil and 2, 4, 5-trichlorophenoxy acetic acid help to retard ripening in plantain and mango, respectively. Compounds having similar properties are used for other fruits.

7.4.2 Sprout inhibitors

Many foods of plant origin like onions, carrots and potatoes that grow beneath the soil surface sprout during storage. Potatoes are especially vulnerable when the storage temperature is moderate (25–30°C) and relative humidity is between 50–80 %. In order to prevent sprouting in potatoes, methyl esters of naphthalene acetic acid, maleic hydride, technazene, propham and chloropropham are employed. Other sprout inhibitors are phenyl carbamate and vapours of nonylalcohol.

7.4.3 Antioxidants

Antioxidants are substances that prevent the reaction of various food constituents with oxygen thereby avoiding deterioration caused by simple oxidative chemical reactions. Oxidative changes occur in unsaturated food components that include fats and oils, carotenoids and porphyrin-like compounds (e.g. chlorophyll, haemoglobin). Fats and oils are particularly vulnerable to oxidation resulting in off-odour development and deterioration in the commodity. Antioxidants such as α-tocopherol, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) isopropyl citrate mixture, and propyl gallate are used to offset the oxidative rancidity in fats and in fried potato chips, salted nuts, crackers, breakfast cereals, fat-containing dehydrated foods and other fatty foods (Table 7.3). Hence, these and similar products remain fresh on the shelf for a much longer period in the presence of the antioxidants than in their absence. Other compounds that exhibit antioxidant characteristics and are used for the purpose include ethoxyquin, L-ascorbic acid (vitamin C), stannous chloride, sulphur dioxide and nordihydroguiaretic acid (NDGA). Again, like all other chemical additives, their use is controlled by food laws.

Table 7.3 Some antioxidants and their applications.

Additive	Foods	Max. level
Alpha tocopherol	Mayonnaise	240 mg/kg
	Canned baby food	300 mg/kg in the fat
	Edible fats and oils	500 mg/kg
Ascorbic acid	Canned mangoes	200 mg/kg
	Mango chutney	200 mg/kg
	Jams, jellies	500 mg/kg
	Canned peaches	550 mg/kg
BHA	Mayonnaise	140 mg/kg
	Margarine	175 mg/kg
	Butter oil	200 mg/kg
BHT	Edible fats and oils	75 mg/kg

Source: FAO/WHO (1990)

The process of rancidity in fats and oils is stimulated, in part, by the presence of metallic ions such as iron and copper. These come in contact with lipids during processing or storage in iron or copper containers or may be part of the food system. In order to prevent contact of these metal catalysts with the unsaturated fats and thus hinder their catalytic action, chemical compounds generally referred to as sequestering and chelating agents are employed to inactivate the metals. Sequestrants or sequestering agents are compounds that are capable of inactivating a metallic ion by forming a complex (usually water soluble) in which at least one covalent or coordinate covalent bond holds the metal in the complex. A chelating agent, on the other hand, is a compound containing two or more donor groups that can combine with a metal to form one or more inner ring structures. These chelated complexes may be water-soluble and are sometimes referred to as sequestered compounds. Examples of compounds capable of sequestering metallic ions in foods are ethylendiamine tetra-acetic acid (EDTA),

polyphosphates and citric acid. Food components like haemoglobin, myoglobin and chlorophyll are naturally occurring chelates.

7.4.4 Antimicrobial agents

Microorganisms are present on the surface of fresh food commodities; these also find their way into processed foods. If these are not inhibited, they will grow and cause spoilage. Whole fruits may be treated with fungicide solutions such as dithane M45 to prevent fungal growth on their surface. The sodium salt of O-phenyl phenol is used as a spray or dip for citrus fruits.

Salt, sugar, wood smoke, vinegar, organic acids, parabens, nitrites, medium chain fatty acids, hydrogen peroxide, phosphates and others are being used as antimicrobial agents in food preservation. Some naturally occurring compounds like nisin and natamycin produced by lactic acid bacteria or those present in spices and herbs are also effective against microbes. Fumigants such as ethylene oxide and ethyl formate help to control microorganisms on spices, nuts and dried fruits.

In the production of pan bread and cakes, sodium and calcium propionates are employed as mould inhibitors, while sorbic acid is used in cheese for the same purpose. Fruits and vegetables may be washed in water containing germicidal substances like chlorine. Potassium or sodium metabisulphite and benzoic acid are common in the preservation of syrups, juices and squashes. In the manufacture of carbonated beverages, in addition to the carbon dioxide, sodium benzoate is a common antimicrobial (Table 7.4). Sodium diacetate (parabens) and a few specific antibiotics are also often employed as antimicrobial agents. Wood smoke chemicals, combined with low water activity, are responsible for preservation of smoked fish and other products.

The choice of antimicrobial agent depends upon several factors. These include properties, safety and cost of the compound, as well as the properties of the food and possible effect of the chemical on its quality. In addition, type and level of microorganisms present, post-processing and storage conditions, as well as food laws of the country must be taken into consideration while selecting an antimicrobial agent.

Concentration of the chemical itself in relation to the medium (food) in which preservative is used influences the effectiveness of the additive. A chemical agent, when used as a preservative, may be bactericidal at a certain concentration, only inhibitory at a lower level and may be completely ineffective at still greater dilutions. The amount of a chemical that can be added to a food is governed by law as some of the chemicals may have adverse effects at certain levels on human health. Thus, for example, sulphur dioxide, a common preservative for many fruit products, can only be added to a maximum of 1,500 ppm (parts per million) in fruit juice concentrates, while in squashes, syrups and fruit juices only 350 ppm are permissible. Similarly, in syrups and sherbets, benzoic acid may be added to a maximum limit of 600 ppm, while only 250 ppm are allowed in tomato puree and paste (Tables 7.4 and 7.5). In relation to concentration of most acid food preservatives, it is the unionized form of the acid, which is responsible for the antimicrobial activity.

Table 7.4 Properties of some antimicrobial agents

Antimicrobial agent	Effective pH range	Antimicrobial activity
Acetic acid	6.5	Gram positive bacteria, Na diacetate used in baked goods as a mould and rope inhibitor
Benzoic acid	2.4 – 4.0	Yeasts and moulds, food poisoning spore forming bacteria
Lactic acid		Spore forming bacteria
Propionic acid	≤5.0	Spore-forming bacteria especially rope bacteria, moulds.
Sulphur dioxide	≤4.5	Yeasts, moulds, bacteria

The temperature of the environment and the length of time food is kept under the influence of a chemical agent also determine the effectiveness of the preservative. Lower storage temperature will add to the preservation powers of the chemical additives.

Chemical and physical characteristics of the food material in which the organisms are found, greatly influence the effectiveness of the preservatives. The moisture content of food, pH, and presence of protective substances such as sugars, salts and fats, all are effective in determining the final role of the chemical additives.

7.5 FOOD LAWS

Food laws are regulations aimed at providing the consumer with foods of the desired quality that are safe, healthy and nourishing. They are intended to protect the public from frauds, negligence of food handlers and unsanitary practices during food preparation and processing. The first law ever to be passed on to mankind was a food

law when the Almighty forbade Adam and Eve from eating the fruit of a particular tree (Holy Bible, Genesis 2:17; Holy Quran, VII:19). The first recorded food laws were passed down through Moses and are part of the Old Testament in Leviticus and Deuteronomy. Islam permits consumption of lawful foods only (Holy Quran, II:173, V:3, VI:146, XVI:115).

Table 7.5 Maximum permitted levels of common chemical preservatives.

Preservative	Permitted in or upon	Maximum level of use(mg/kg)
Benzoic acid	Margarine	1000
	Pickled cucumbers	1000
Calcium hydrogen sulphite	Jams, jellies	200
Potassium ascorbate	Wheat flour	300
Potassium benzoate	Mango chutney	250
Potassium metabisulphite	Mango chutney	100
Potassium sorbate	Dried apricots	500
	marmalade	500
Propionic acid	Processed cheeses	3000
Sodium benzoate	Mango chutney	250
	Margarine, mayonnaise	1000
	Jams, jellies	1000
Sodium sorbate	Dried apricots	500
Sorbic acid	Vinegar	400
	Dried apricots	500
Sulphur dioxide	White sugar	20
	Glucose syrup	40
	Jams, jellies, marmalade	100
	Raisins	1500
	Dried apricots	2000

Source: FAO/WHO, 1990

The present day food legislation stems from the fact that unscrupulous food handlers and traders started adulterating foods. In the United States the earliest legislation dealt with the adulteration of flour. During the period from 1880 to 1906, over one hundred bills were introduced into the Congress, which culminated in passing Pure Food and Drug Act of 1906. This Act formed the basis for the present day food legislation in the United States. It has given rise to the Federal Food, Drug and Cosmetic Act of 1938.

The British food laws have been used as the basis in all Commonwealth countries. In Pakistan, food laws passed by different provinces from time to time (e.g., Punjab Pure Food Rules, 1930; Sindh Food Rules, 1949; The Karachi Food Rules, 1958) were consolidated into Pure Food Ordinance 1960. This later was amended to The West Pakistan Pure Food Rules, 1965, now called Pure Food Rules. Besides these rules, different Acts, Rules, Orders and Ordinances are in force on distribution, movement and processing of wheat, rice, tea, sugar cane, hydrogenated vegetable oil, meat, etc.

In general, food laws are aimed at protecting the consumer and providing him with wholesome foods of the desired quality. The food laws prohibit the sale and consumption of adulterated, contaminated, misbranded, substandard and potentially harmful foods. Food standards are being formulated in Pakistan for different foods. These are aimed at setting guidelines for the quality of the processed foods.

"WEAR THE OLD COAT
BUT BUY THE NEW BOOK"

8

USE OF FERMENTATIONS

Fermentation is the anaerobic or partially anaerobic oxidation of carbohydrates. During this process, enzymes, elaborated by microorganisms, breakdown carbohydrates or carbohydrate-like materials into substances that are less subject to undesirable microbial activity than the original material. Contrary to other food preservation techniques, in this method, the activities of desirable microorganisms are promoted. Optimum conditions of temperature, hydrogen ion concentration (pH), oxygen supply, nutrients and water activity are maintained to promote their growth.

8.1 FERMENTED FOODS

Traditionally, fermented foods are an important part of the diet all over the world. In the less developed and technically backward countries of Asia, Africa and Latin America, fermentation is an important technique to extend the shelf life of food raw materials. In the technologically advanced countries of Europe and North America, it is used more for the flavour and variety that is added to the diet. The present day fermentation industries (e.g., baking, brewing, wine making, vinegar manufacture) which employ pure cultures grew out of the home-scale traditional fermentation processes that relied primarily on the activities of mixed microflora. However, several modern fermentation plants still utilize mixed or conjoint microbial cultures to produce fermented foods (e.g., yoghurt, cheese, sauerkraut, pickles).

The present day fermentation industry is enormous and utilizes different raw materials and microorganisms to produce several end products. There are more than 3500 fermented foods consumed in the world. Numerous beverages are produced by fermentation. These include alcoholic beer, wine, brandy, whisky, vodka, sake, and palm wine) and non-alcoholic beverages (tea, coffee, and cocoa). Cereals are fermented to produce leavened bread, pancakes, muffins, *jalebi*, *'idli'* and *'dosa'*. Legumes are fermented in the Far East (China, Japan, Indonesia) for the production of *tempeh*, *soy sauce*, *miso* and *oncom*. Soybeans and some press-cakes (e.g. ground-nuts) are used as primary raw material for soy sauce and *miso* in which moulds and lactic acid bacteria play important roles. Soybeans are also fermented by the help of moulds to produce *tofu*, *sufu* and *tempeh* that are consumed as such or are fried before eating. Similarly, rice serves as a source of raw material to produce *ang-quac* (colouring substance), *temari* sauce (seasoning), *sake* (drink) and *idli* (a staple food prepared in the form of steamed cakes).

Fermented fruits and vegetables are traditionally consumed in Pakistan and India. Raw mangoes, ripe limes, olives, turnips, carrots, onions, cauliflower, reddish, pepper and others are pickled with the help of mainly lactic acid bacteria. In these fermentations other microorganisms also contribute to the characteristics of the final product. Among the dairy products, cheese and yoghurt are popular, while kefir and kumis are also produced in some regions of Europe. Fish is fermented in North Africa, Middle East, Europe and South East Asia. Sausages and salami are produced from meat. In Nigeria, several fermented foods constitute a major portion of the diet. Among these are some used as staple food (*gari*, *ugba*), breakfast gruel (*ogi*), beverages (palm wine, *burukutu*, *pito*) or condiments (*ogiri*, *dawadawa* and *afzelia bella-bella*).

8.2 OBJECTS OF FERMENTATION

Fermentation, offers means of producing a special group of food items. It has as its primary objective, the prolongation of the keeping quality of food raw materials especially in areas where other methods of preservation are technically and economically difficult to implement. Since the process involves growth and proliferation of microorganisms, several changes simultaneously take place in the original food material. Fermentation may enhance flavour of some foods, while in others it improves the physical characteristics. In some cases, it completely alters

the parent foodstuff to a new and different product. The new product invariably has a longer shelf life than the parent raw material.

8.3 TYPES OF FERMENTATIONS

8.3.1 Alcoholic Fermentation

Alcoholic fermentation is applied in the production of leavened bread and alcoholic beverages. In this fermentation, sugars are converted into ethyl alcohol and carbon dioxide according to the simplified equation below: -

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Yeast}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + 2CO_2$$

Several yeasts can be used, but most commonly species of the genus *Saccharomyces* such as *S. cerevisiae* and *S. carlsbergensis* are employed. Ethyl alcohol and, to some extent, carbon dioxide act as natural preservative agents in such fermented products.

Alcoholic beverages – Beer is produced from barley. In a separate process, the barley is allowed to germinate under controlled conditions to produce malt that contains active enzymes from the germination process. These help in the breakdown of starch. The malt is cleaned, weighed and adjuncts added, if necessary. It is mashed to digest and dissolve as much as possible the valuable portions of the malt and malt adjuncts. This is passed through filtration process after which the filtrate (now called wort) that contains fermentable sugars and other necessary nutrients for the yeasts, is boiled with hops to inactivate the enzymes, extract soluble substances from the hops and precipitate coagulable proteins. The wort is allowed to ferment in special vessels (Fig. 8.1) with the aid of selected strains of brewery yeasts (*S. cerevisiae*, *S. carlsbergensis*). The fermented wort is filtered to remove yeast cells and other coarse particles. The young beer, as it is now called, is allowed to mature in storage vessels. It is filled in bottles and pasteurised. This gives the finished product additional preservation effect. The final product contains between 3 and 5 per cent ethyl alcohol. Further in situ preservative action, other than that of carbon dioxide and ethyl alcohol, is derived from the hops or hop extract that is added into the mash for taste and flavour.

Wines may be manufactured from any sugary raw material. Fruits are commonly used for the purpose. Wines produced from grapes (*Vitis species*) are regarded as the real wines, while those made from other fruits are simply referred to as fruit wines, but more specifically designated with the name of the fruit used as a prefix to the word wine, e.g. banana wine, mango wine, etc. Selected grapes or fruits of proper maturity are crushed and treated with sulphur dioxide or sulphite or pasteurised to reduce the microbial contaminants. This is then inoculated with a suitable yeast starter and allowed to ferment. After a short fermentation, the wine is drawn off, placed in storage tanks for further fermentation, racked, stored for ageing, clarified and packaged.

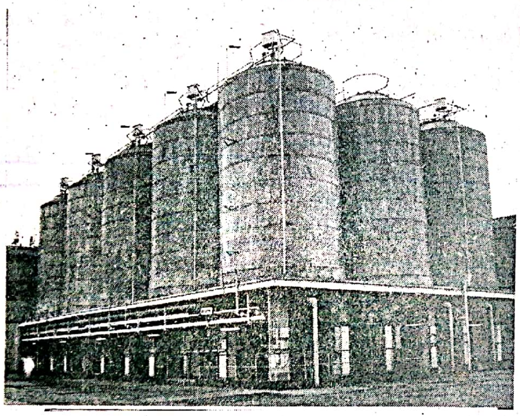

Fig. 8.1 A battery of fermenters

Champagne is manufactured from specially selected white table wines produced from grapes. This involves a secondary fermentation that yields more ethyl alcohol, carbon dioxide and flavour in the product. Spirits such as whiskey, brandy, gin, rum and vodka are obtained by distilling various fermented liquors. Whiskey is prepared from malted barely (malt whiskey) or grains (grain whiskey) by fermentation and subsequent distillation. Grape wine is the usual raw material for brandy while rum is produced from sugar juices or molasses. Gin is prepared by distilling fermented maize or rye worts and adding juniper and other herbs to the distillate.

The normal percentage of alcohol in wines varies from as low as 3 to about 15 per cent while in the distilled beverages (spirits) it may range from 40 to 50 per cent. The keeping quality of alcoholic beverages depends mainly on the percentage of ethyl alcohol present in the product—higher the alcohol content, longer the shelf life. Excluding air to

prevent the activities of aerobic organisms further prolongs the shelf life of alcoholic beverages.

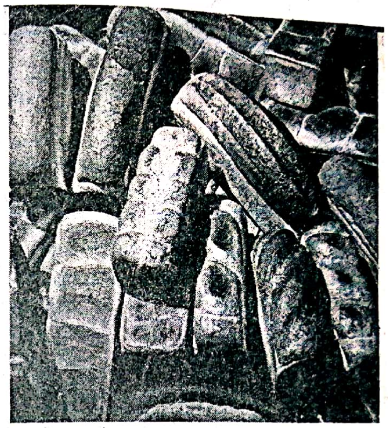

Fig. 8.2 Pan bread — a product of alcoholic fermentation

Bread manufacture – In the manufacture of pan bread and similar products, the essential ingredients (wheat flour, yeast, water and salt) are mixed together and made into dough of desired quality by stretching, folding and cutting. This is allowed to ferment—the yeast utilizes sugars and produces carbon dioxide and minor amounts of ethyl alcohol. The carbon dioxide is trapped in the gluten framework of the dough to give an increased volume. The dough is then scaled off into pieces of definite weight and placed in moulds, which are allowed to rest or 'prove' in warm and slightly humid conditions. The moulds are now placed in baking ovens and the bread baked. Even though ethyl alcohol is a product of yeast fermentation in bread production, the object in this case is to produce carbon dioxide, which when trapped by the developed dough, gives it a risen appearance. The ethyl alcohol normally evaporates in the baking process. The fermentation process, in case of bread production, is not aimed at increasing the shelf life, but to impart certain textural characteristics to the product such as increased volume and open crumb. Leavened bread is slightly more nutritious than the unleavened one made from the same ingredients on account of the vitamins and proteins that the yeast contributes to the fermented dough.

8.3.2 Acetic Fermentation

Acetic acid bacteria (species of the genera *Acetobacter* and *Acetomonas*) are capable of oxidizing ethyl alcohol into acetic acid and water according to the following simplified equation: -

$$\underset{\text{Ethyl alcohol}}{C_2H_5OH} \xrightarrow{\text{Acetic acid bacteria}} \underset{\text{Acetic acid}}{CH_3COOH} + H_2O$$

This organic acid is produced when the activities of acetic acid bacteria are harnessed in the acetuous fermentation of alcoholic substrates. Acetic acid is the main component of vinegar, which has been used for centuries as a medicine, flavouring agent and preservative for products like tomato ketchup, mayonnaise and salad dressings (the latter two are emulsified semi-solid products prepared from vegetable oil, egg yolk and vinegar). Many pickles are also partially preserved by using vinegar, while others are prepared exclusively by immersing vegetables in vinegar (e.g. onions, cucumbers).

Vinegar production – Vinegar is a product of acetic acid fermentation. In commercial production, suitable cheap raw material such as grapes, apples, malt, sugar or molasses is fermented by yeasts to produce ethyl alcohol. This yeast-fermented substrate is allowed to undergo acetuous fermentation by the slow or quick process. The slow process has almost become obsolete due to being inefficient and producing low quality vinegar. Furthermore, it involves large capital investment. In the improved version of the slow process, called Orléans Process, the fermented liquid (alcoholic substrate) is filled in special barrels. This is inoculated with fresh vinegar. After about three months at 21 to 29°C, about 1/3 is withdrawn and fresh quantity of the fermented liquid added. The freshly acetified vinegar is stored and aged for about 6 months to improve its flavour and other characteristics. It is then clarified, bottled and pasteurised. Every month about 1/3rd to 1/4th of the finished vinegar is withdrawn and the cycle is repeated.

The Quick or Generator process consists of an upright cylinder of varying dimension. It is equipped with a spreader device to distribute alcoholic solution, a large main section filled with maize cobs, purified coke or charcoal or Beachwood shavings to provide surface to the acetic acid bacteria and a lower section with air holes. The fermented liquid is sprinkled from the top and air is pumped from the bottom. The acetic acid bacteria present on the corncobs, etc. convert ethyl alcohol into acetic acid. When the conversion is completed, the vinegar is drawn, aged, clarified and filled into bottles.

Food laws require that vinegar must be produced by acetic fermentation of alcoholic material obtained by fermentation of suitable sugary raw material. It must contain at least 4 per cent acetic acid. Most vinegar available in Pakistan is manufactured by simply diluting glacial acetic acid to about 4 per cent concentration, adding some colouring and selling the product as vinegar. This is referred to in trade as synthetic vinegar.

8.3.3 Lactic fermentation

Based on the number of fermented products available today, lactic fermentation is by far the most widely used biological preservation technique. It is employed in the meat industry in the manufacture of several meat products including special fermented sausages (e.g., salami, bologna). In the dairy industry, it is important in the production and preservation of sour milk products such as acidophilus milk, yoghurt, cultured butter milk, etc. in addition to sour cream, butter, all types of cheeses and numerous other products. Several fruits including raw mangoes, olives, and ripe limes and vegetables such as cucumbers, cabbage, turnips and lettuce have been converted to new products by the activities of lactic acid bacteria. These organisms utilize sugars present in the foods and convert them into lactic acid, viz:

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Lactic acid bacteria}} \underset{\text{Lactic acid}}{CH_3CHCOOH} + H_2O$$

The preservative characteristics of lactic fermentation are due to the conversion of sugary substrates present in the food to lactic acid. This lowers the pH and raises the acidity of the food, thereby preventing growth of most other bacteria. Moreover, lactic acid in the unionised form is toxic above certain concentrations to most bacteria including lactic acid bacteria themselves.

Dairy industry – In the dairy industry, species of the genera *Streptococcus*, *Lactobacillus* and others are most often utilized to convert milk sugars to lactic acid. In the production of yoghurt, for example, standardized and pasteurized milk is inoculated with a culture containing *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. The lactic acid produced coagulates the milk proteins. The coagulated milk product may be consumed as such (sour milk, yoghurt), or further processed to produce cheese. The basic preservative agent in these products is lactic acid, which lowers the pH plus the additional effect of high total solids concentration, as in cheeses. Other preservation techniques such as pasteurisation, packaging and storage conditions ensure further extension in shelf life.

Meat industry – Lactic fermentation, in the production of numerous meat products (sausages), is primarily directed towards obtaining a low pH (4.0 to 5.5) and the production of unique flavour characteristic of the product. Strains of *Leuconostoc*, *Lactobacillus* and *Pediococcus* are employed for this purpose, while preservation may be by any appropriate technique.

Fruit and vegetable industry – By far the most important use of lactic fermentation in the food industry worldwide is in the fermentation of fruit and vegetable materials to produce pickles or other products. Several raw materials like cucumbers, olives, cabbage, turnips, limes, unripe mangoes and green pepper are used. Fermentation is carried out by species of *Lactobacillus*, *Leuconostoc*, *Pediococcus* and other suitable lactic acid bacteria. The activities of other microorganisms in these products are suppressed by the addition of common salt (2.5% or higher). The rationale for choosing the level of salt is that most lactic acid bacteria responsible for bringing about the desired changes can tolerate salt concentration to a certain extent. Furthermore, salt inhibits the activities of putrefactive, lipolytic and other food spoilage organisms.

For the production of pickles, the raw material is washed, trimmed and cut, if necessary. The required quantity of salt is added. This is allowed to undergo fermentation by natural microflora. The desirable bacteria grow on the vegetable juice which is osmotically extracted with the help of salt. The lactic acid produced lowers pH of the product and helps in its preservation. However, the vessel containing the product must be kept air tight to prevent proliferation of aerobic spoilage microorganisms.

8.4 CHANGES IN FOODS AS A RESULT OF FERMENTATION

During controlled fermentations the growth and activities of microorganisms resulting from the existence of a favourable environment lead to the breakdown of complex components of food molecules into simpler ones. These substances get metabolised into end products and are released in the environment. The three major components in foods that are metabolised by microorganisms are the carbohydrates, proteins and fats.

When carbohydrates or carbohydrate-like compounds are attacked by microorganisms, end products such as alcohols, organic acids, aldehydes and ketones are released in the environment. Since

these compounds are only slightly more oxidized than the original carbohydrates, they can yield energy on further oxidation. The human body can utilize some of them as immediate sources of energy. However, quite a number of these intermediate carbon containing compounds possess antimicrobial properties and, therefore, foods containing them are less prone to attack by some groups of microorganisms.

Most foods from natural sources contain some percentage of proteinaceous substances. The breakdown of proteinaceous material is referred to as proteolysis. Lipolysis is the term that describes the breakdown of fatty materials. Both proteolytic and lipolytic reactions usually produce off-odours in the product depending upon the degree of changes. In food fermentations, the activities of proteolytic and lipolytic microorganisms are controlled and only the beneficial fermentative organisms are encouraged to produce the desirable effects in food materials.

The end result of controlled activities of microorganisms in food systems is, that part of carbohydrates are converted to mainly alcohols or organic acids, while proteins and lipids may be broken down to the extent that these do not produce compounds with obnoxious odours. During the growth of microorganisms several vitamins and amino acids are also synthesized so that the fermented product usually has an increased nutritive value than the original substrate.

NOTES

"READING IS TO THE MIND WHAT EXERCISE IS TO THE BODY"

9

USE OF IRRADIATIONS

The solar system is an important natural source of electromagnetic waves to the earth. These are oscillating electric fields travelling through space accompanied by similar oscillating magnetic fields in a plane at right angle to them. In other words, electromagnetic waves are simply electric and magnetic fields and possess energy like any other field in nature (e.g. gravitational field). The energy content of these waves depends upon their frequency – higher frequency corresponds to higher energy.

9.1 UNITS OF MEASUREMENT

The S.I. units for wavelength and frequency are "Angstrom" (A°) and Hertz (Hz), respectively. The smaller wavelengths are normally described in Angstrom or nanometers (nm), while longer ones are stated in larger units (meters). Frequency is designated by Hertz or multiples of Hertz (Hz, KHz, MHz). The energy as absorbed by food is now measured in terms of Gray (Gy) or kilogray (kGy). One Gray equals one Joule (J) of energy absorbed per kilogram of food being irradiated. The earlier unit for this measurement was "rad" (equivalent to 10^{-5} J of energy absorbed per gram of material receiving ionising radiation). One Gray corresponds to 100 rads and kilogray to 1,00,000 rads or 1 J/kg.

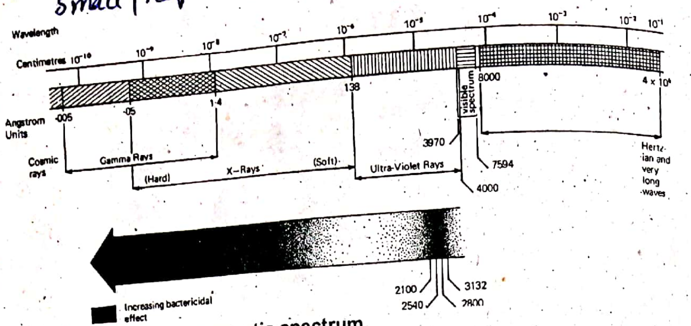

Fig. 9.1 The electromagnetic spectrum

9.2 CHARACTERISTICS OF ELECTROMAGNETIC WAVES

The electromagnet waves forming the electromagnetic spectrum vary in their wavelengths and hence their characteristics. Visible light, from the sun or any other source, is only small fraction of the spectrum and covers a wavelength range of 400 – 700 nm. The radiations from this fraction are directly beneficial to all forms of life. Along with the visible portion of the spectrum, the infrared rays (wavelength, 700 - 300,000 nm) reach the earth from the sun. Microwaves are still longer in wavelength, ranging from 3 x 10^8 – 10^7 nm. Infrared and microwave radiations have found practical applications for heating in cooking gadgets. Electromagnetic waves having wavelengths of 10^6 – 10^{13} are known as radio waves and are primarily employed in radar system, television broadcasts and radio sound transmissions.

The ultraviolet rays have a shorter wavelength than visible light (10 – 400 nm). These possess germicidal characteristics – the most effective range being between 200 to 280 nm. X-rays are still shorter, 0.01 – 15 nm while gamma rays occupy a band among the X-rays and have a wavelength ranging from 0.0005 – 0.14 nm. The X-rays arise from energy changes associated with the electronic structure of atoms; while gamma rays originate from energy changes in the nuclei of atoms. Gamma and X-rays have germicidal properties and are being exploited in the food industry.

9.3 SOURCES OF ELECTROMAGNETIC RADIATIONS

Electromagnetic radiations can be produced from different sources. Infrared are produced by all matter over a wide range of temperature from absolute zero upwards. The most common source for commercial use includes electrical devices incorporating transmitters of

IR radiation such as quartz and rock salt. Microwaves are produced by magnetron tube. The ultraviolet radiations are normally emitted by very hot bodies, e.g. electric arc or by electric discharge through gases, particularly mercury vapours in quartz envelopes.

For food preservation by irradiation, X-rays are generated from machine sources operated at or below an energy level of 5 micro-electron volts (MeV). Gamma rays are emitted from the radionucleoide ^{60}Co. Electrons are generated from machine sources operated at or below an energy level of 10 MeV.

9.4 USE OF ULTRAVIOLET RADIATIONS

The ultraviolet (UV) radiations are absorbed by purine and pyrimidine groups of the nucleic acids in microbial cells. This invariably results in mutation (a permanent change involving genetic material) and eventually death of the organism. Special lamps are available that emit these radiations at the most germicidal wavelength (200 to 280 nm). Some ozone is formed during the operation of UV lamps. The visible range of these lamps has an irritating effect on the skin and gazing at its source produces irritation in the eyes.

In the food industry, ultraviolet rays are employed in sterilizing equipment especially in microbiology laboratories and space in cold storage and freezer chambers. These rays are also used in the treatment of water for beverages; in killing spores on sugar crystals and syrups; in treating pickles, vinegar and sauerkraut to prevent the growth of film yeasts and in the storage and packaging of cheese.

9.5 USE OF IONIZING RADIATIONS

Ionizing radiations are of short wavelength from the electromagnetic spectrum plus highly accelerated intra- and extra-nuclear particles such as electrons, protons, alpha particles and neutrons. These include X-rays as well as alpha, beta and gamma rays from the atomic fission of radioactive substances such as cobalt 60 (^{60}Co) and caesium 137. Gamma- and X-rays and highly accelerated electrons are commonly used for food preservation. These are absorbed by all forms of matter. Gamma rays have much greater penetrating power than other radiations (Fig. 9.1).

Living cells are particularly sensitive to these forms of ionising radiations, which promote changes that may lead to mutation and death of the cell. The dose required for such changes varies from one organism to another. A dose of up to 0.1 Gy (10 rads) has no apparent effect on living organisms, but 1 to 10 Gy (100 to 1000 rads) would be lethal to man. Insects require approximately 0.01 to 1 kGy (0.001 to 0.1 Mrad), while microorganisms may need a much higher dose as an effective lethal dose.

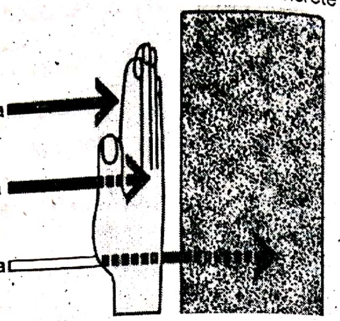

Fig 8.2 Penetrating power of alpha, beta, and gamma radiations.
(Source: Radiation -- A Fact of Life, IAEA, Vienna, 1994).

9.6 COMMERCIAL APPLICATIONS OF IRRADIATIONS

The commercial applications of irradiation have been slow due mainly to economic handicaps, lack of realistic techno-economic feasibility studies, lack of acceptance of the process by national governments and reluctant attitude of consumer towards the consumption of such foods. It is claimed that radiations bring changes in food materials that are not fully understood and that products of radiolysis could prove toxic.

Based on extensive research, it has been recommended by the Joint Expert Committee on Wholesomeness of Irradiated Foods that "any food irradiated to an average dose of 1 Mrad (10 kGy) or less is wholesome for humans and, therefore, should be approved without further testing". Proven applications of radiation processing include: -

a. destruction of pathogenic bacteria and parasites of public health significance in raw and minimally processed foods;
b. microbial decontamination of spices and dried vegetable seasonings;
c. insect disinfestations of grains and other stored products;
d. inhibition of sprouting in bulb, tuber and root crops;
e. shelf life extension of fruits and vegetables by delaying maturations, ripening and microbial spoilage;

f. control of insect pests in fresh fruits and vegetables for quarantine purposes;
g. enhancement of the refrigerated shelf life of meat, poultry, seafood and fresh fruit and vegetables by reduction of spoilage causing microorganisms.

A unique advantage of employing ionising radiations lies in their strong penetrating power. Materials to be treated can be exposed to radiations in their final packaging, thus avoiding any potential risk of recontamination. The irradiated food should be prepared, processed and transported hygienically.

As a result of the clearance and recommendations by the Codex Alimentarius Commission, over 40 countries have approved the use of food irradiation for one or more food or food groups and over 30 countries are using it for commercial purposes. The clearance has been provided for food items including potatoes, onions, garlic, some cereals, wheat flour, whole wheat flour, strawberries, mangoes, dried vegetables, powdered eggs, food extracts, paprika, spices, seasonings, coconut powder, shrimps, frozen prawns, frozen frog legs, and chicken. According to some estimates, as of 1999, total irradiated food processed worldwide stood at 243,000 metric tones.

9.6.1 Sprout Inhibition

Coordinated research efforts have established the technological feasibility of irradiation for sprout inhibition in potatoes, onions and garlic. The use of radiations at levels of 30 to 150 Gy (0.003 to 0.015 Mrad) or less inhibits sprouting in tubers and bulbs, thereby extending their storage life. Government of India permits 30 to 90 Gy for irradiating onions and 60 to 100 Gy for potatoes.

9.6.2 Insect disinfestation

Several fresh produce (citrus fruits, mangoes, lentils), dried fish and spices are often infested with insect eggs, larvae or adult insects. At present most consignments are fumigated. Owing to suspected toxicity problems, use of some fumigants like ethylene oxide and ethylene dibromide has been prohibited or restricted in some countries for the treatment of spices.

Disinfestation by irradiation is an effective alternate to fumigation. It is a continuous process and requires a relatively short period of treatment. Since irradiation also increases shelf life of fruits and vegetables by delaying ripening, the marketing period of these foods is also extended by 2 to 5 days. A dose of 0.2 kGy (0.02 Mrad) is sufficient to destroy insect eggs, larvae and render the insects themselves incapable of further reproduction. In dried and smoked fish, about 2 kGy is required to kill 99 per cent larvae, although lower dose (0.2 kGy) will prevent the larvae of all fly species from developing into adults.

9.6.3 Radiation pasteurisation

Radiation pasteurisation can be applied to: -

a. reduce microbial population in spices and dry ingredients. This treatment is technically termed as radurization - radiation pasteurisation designed to kill or inactivate food spoilage organisms.

b. kill or render harmless all disease-causing organisms (except viruses and spore-forming organisms) – a treatment technically called radicidation.

Radurization – When fruits, vegetables and meat are destined for cold storage, it is desirable to have minimum number of microbial cells on their surface. Ionising radiations at a dose of 0.2 kGy to fruits and 3 to 5 kGy to meat can be applied to disinfect their surfaces and extend their life during cold storage. Similarly, spices, which carry heavy contamination of microorganisms on their surfaces, can be successfully decontaminated by the application of 4 to 5 kGy (0.4 to 0.5 Mrad) of radiation without adversely affecting the volatile constituents of the product. This treatment is considered superior to the use of chemical fumigation that leaves toxic residues. Moreover, the shelf life of fruits like strawberries and fresh fish can also be extended by radurization.

Radicidation – Food can also be made safe for human consumption by the application of irradiation in the process called radicidation. Low doses of irradiation (below 10 kGy) are helpful in the destruction of parasites and food poisoning bacteria in meat and poultry. Destruction of parasites such as *Trichinella spiralis* and *Taenia saginata* is achieved at a dose of 0.1 to 0.3 kGy, while doses of up to about 5 kGy (0.5 Mrad) are necessary to kill non-sporing pathogenic bacteria like *Salmonella, Vibrio parahaemolyticus, Staphylococcus aureus* and others. Frozen meat, poultry, eggs and other foods liable to contamination with pathogens can be given irradiation treatment of below 10 kGy (1 Mrad) to destroy the pathogens. Radiation pasteurised foods (radicidized or radurized) like the heat pasteurised, must be stored under refrigeration.

9.6.4 Radiation sterilization – Radappertization

Irradiation is largely being used to sterilize medical devices and supplies. This requires a dose of 100 kGy (10 Mrad) or higher. If applied to foods, it will be highly damaging to its quality. Therefore, similar to commercial sterilization, radiation treatments can be given to food to destroy all pathogens, most food spoilage organisms, as well as the spores of *Clostridium botulinum*. Such a treatment is termed as radappertization and the resulting food can be stored at room temperature, in the same manner as thermally processed food.

Food designated for radappertization is blanched, pre-packaged and sealed under high vacuum to remove oxygen. This is then frozen to –40°C and irradiated to a dose of about 10 to 50 kGy (1 to 5 Mrad) while in frozen state. The freezing step acts to minimize the possibility of nutrient loss or flavour changes during irradiation. After irradiation, the treated food is allowed to thaw in the package and stored without refrigeration, as are heat processed foods. A dose of up to 10 kGy has been found to present no toxicological hazards. The radappertized foods present no health hazards. However, when irradiation is used as an adjuvant to heat for commercial sterilization, it augments the sterilising efficiency of heat and does not have adverse effects on the food material.

Most research conducted in this direction has been limited to a few foods: meat, poultry, fish and some vegetables. Dairy products have been found unsuitable for radappertization, since undesirable flavour changes occur in the irradiated product. Radiation sterilized foods have been enjoyed by the American astronauts and some hospital patients, such as organ transplant recipients, who are confined to special sterile environment.

9.6.5 Delayed Ripening

The ripening process in fruits such as bananas, tomatoes, pears, mangoes, guavas and others can be delayed by low dose irradiation (250 to 350 Gy). Also, the shelf life of fresh mushrooms can be extended by an irradiation treatment, which will prevent the growth of stem and opening of the caps. If this is combined with proper packaging and storage temperature, the shelf life can be doubled.

9.6.6 Other Applications

The dependence on chemicals in such processes as cured meat products can be reduced or completely eliminated by the use of irradiation treatment. This application can also be used to bring about desirable chemical changes in certain food products. For example, a dose of 10 to 20 kGy (1 to 2 Mrad) of irradiation hastens the ageing process in alcoholic beverages. Similarly, the odour in essential oils may be enhanced by treatment with a dose of 10 kGy (1 Mrad) of irradiation. In case of dehydrated vegetables, the time required for rehydration may be reduced by a dose of 2.5 to 25 kGy.

9.7 EFFECT OF IRRADIATION ON FOODS

Irradiation can cause a variety of changes in living cells. Low doses can interfere with cell division and alter the biochemical reactions involved in the ripening of fruits. High doses can kill the cells, thereby destroying microorganisms and insects. The chemical changes brought about by irradiation treatment depend upon the food to be exposed, the type of packaging, and processing conditions such as temperature during irradiation and storage time. However, based on extensive research, it has been established that many of the substances produced by irradiation and identified through the use of sensitive analytical techniques are familiar ones that exit in non-irradiated foods. These are also formed as a result of conventional processing such as boiling, frying and grilling.

A few new substances called radiolytic products may be formed. The United States Food and Drug Administration has estimated that the total amount of undetected radiolytic products that might be formed when food is irradiated at a dose of 1 kGy would be less than 3 mg per kg of food or less than 3 ppm.

Ionising radiations are capable of initiating different changes in food systems and formation of certain chemically active substances. The treated food is not heated and, therefore, shelf-stable products are produced that are closer to the fresh state in texture, flavour and colour. The food retains its freshness and physical state.

9.7.1 Effect on Water

When ionising radiations strike the water molecule, the molecule is split – technically called `radiolyzed'. Several intermediate compounds such as `excited water', `free radicals of hydrogen and hydroxyl', `ionised water molecules' and `hydrated electrons' result. When these intermediates react with one another and with other components of the food system in the presence of air, they produce hydrogen gas (H_2), hydrogen peroxide (H_2O_2), hydronium ion (H_3O^+) and hydroxyl ions (OH^-) in addition to water itself. Most food components are capable of reacting

with the intermediates or end products of water radiolysis. The final complexes resulting from such reactions may bring about changes that affect colour, odour, taste or quality of the food material. There is no evidence that any of these compounds is dangerous for consumption.

9.7.2 Effect on Carbohydrates

In carbohydrates, oxidation as well as condensation reactions similar to non-enzymatic browning predominate. It has been suggested that some products of irradiation of sucrose may have toxic effects on cells. Starch and pectin are very sensitive to radiation.

9.7.3 Effect on Proteins

In proteins, deamination, oxidation, polymerisation, and decarboxylation have been observed during irradiation. Histidine, phenylalanine, thyroxine and sulphur-containing amino acids are reported to be most sensitive to the effect of irradiation.

9.7.4 Effect on Lipids

Many reactions result in lipids, which are similar to oxidative rancidity. Several carbonyl (>C=0) containing compounds may be formed. The production of carbonyls and other potentially dangerous substances have led to the vast testing of irradiated foods for possible health hazards.

9.7.5 Effect on Vitamins

Since no cooking or heating is involved in `pasteurising' or `sterilizing' doses of irradiation, the food remains in `fresh' state. The losses are generally less if oxygen is excluded and if the temperature during irradiation is low. Vitamins A, E, C, K and B-1 in foods are relatively sensitive to radiation, while riboflavin, niacin and vitamin D are much more stable. Vitamin losses caused by irradiation are comparable to, or often less than, those produced by other processes used to achieve the same goal.

NOTES

YOU WILL NEVER FIND TIME FOR ANYTHING,

IF YOU WANT TIME YOU MUST MAKE IT

10

FOOD PACKAGING

Packaging may be regarded as a preservation method in its own right or an important adjunct to other methods of food preservation. The main role of packaging is to protect the product during handling, distribution and storage against environmental and mechanical hazards. Even though packaging may perform functions other than preservation, its most important role is to deliver fresh and manufactured foods of the expected quality to the consumer. To do this, the fabrication of each package must be based on an accurate knowledge of the specific sensitivities of the product, the climatic and mechanical stresses expected on the package during handling and turnover time between production and consumption.

Besides the conventional packaging, "Active Packaging" is also being introduced into the market. This packaging responds to the environmental changes. It makes use of electronics and microelectromechanical .system (MEMS) which can detect pressure, acceleration, humidity, temperature, and other environmental variables. The dominant applications are time-temperature integrators (TTI). These devices exploit a change in a physical or physicochemical property to produce irreversible evidence of exceeding predetermined temperature threshold or record the cumulative time-temperature history. The Active Packaging senses and measures variations in the environment or the package and its contents and communicates to the observer. It allows the consumer to know the condition of the food inside the packaging.

10.1 CHARACTERISTICS OF A PACKAGE

Packages for foods, in general, should: -

a. be low cost and non-toxic,
b. be fat- and water-proof,
c. provide barrier against light, gases and water vapours,
d. provide sanitary protection to the food,
e. be of lightweight, easily filled, poured and disposed off,
f. be sealable, printable and tamper-proof,
g. have reasonable impact resistance and mechanical strength,
h. exhibit adequate transparency where practicable.

With the present trend of self-service distribution, the package is also expected to supply information on nutritional nature of the product, method of preparation, storage conditions, expected shelf life and other special information of likely interest to the consumer. The international trading demands that packaging should be able to withstand the pressures of long distance transportation.

Factors considered in selecting a package for a food product are illustrated in Fig. 10.1. These deal with how best the mechanical and handling properties of the package material cut down the adverse effects of spoilage and deteriorative agents on food nutrients with time at convenient and low cost to the consumer.

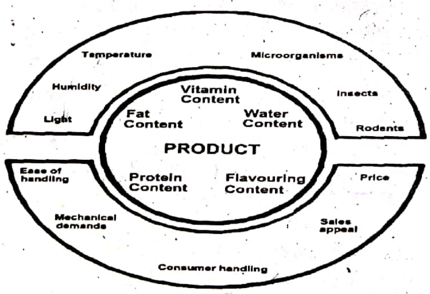

Fig. 10.1 Factors considered in selecting a packaging unit

10.2 PACKAGING MATERIALS

Food packaging utilizes a variety of rigid, semi-rigid or flexible materials made into different forms. These include: –

a. Rigid metals made into cans and drums.
b. Flexible metals made into wrapping foils.
c. Glass made into bottles and jars.
d. Rigid and semi-rigid plastics made into squeeze bottles and canisters.
e. Flexible plastics, cellulosics and paper made into wrappers, pouches and bags.
f. A combination of paper, plastics and flexible metal foils made into multi-layer composite packages.

10.3 RIGID AND FLEXIBLE METALS

Of the many metals that exist in nature, only a few have found use as food packaging materials. These are steel, tin, aluminium and chromium. Metal-based packages come in the form of rigid cans or flexible foils.

10.3.1 Rigid Metal Containers – Tin can

The most common rigid metal container for food packaging is the tin-plate can, commonly called tin can. As a container suitable for the heat processing of foods, it offers a number of unique and favourable combinations of properties that include: –

a. Good appearance and relative low cost.
b. High chemical inertness and lack of toxicity.
c. Good mechanical strength and sealing properties.
d. Good resistance to thermal shock.

10.3.1.1 Three-piece tin can

An important characteristic of the three-piece tin plate can is its ability to offer a hermetic seal capable of withstanding the pressures of retorting. This rugged property is the result of the way in which the can is manufactured. The essential steps in the fabrication of three-piece tin can production start with the manufacture of especially coated steel plate.

a. Steel plate – The type of steel base-plate for can manufacture depends on its ability to withstand corrosion caused by different foods. For example, type L-steel is good corrosion resistant and is useful for cans intended for high acid foods. Type MR is similar in metalloid content to type L but is less restricted in residuals. Similarly, MC and M steels show a decreasing ability to resist corrosion and are used for foods of correspondingly lower corrosive nature or of higher pH values.

b. Tin coating – The steel plate is coated with a thin protective layer of tin. Typical quantity of tin deposited is usually less than one percent of the total can thickness. It is currently being applied to the steel base plate by electrolytic plating, depending on the nature of product to be packed. Electroplating is well suited to the application of a specified thickness of tin on steel unlike the older less common hot dipping technique which relied on drawing sheets of steel through baths of molten tin. The weight of tin coating is expressed as pounds of tin per base box (112 sheets of 14 x 20 inches of common tin plate and weighing about 1 Cwt) or as grams per m^2 and ranges from 2.8 to 11.2 for electroplating.

c. Lacquering – Further protection of the tin plate against the corrosive action of certain fruits and vegetables is provided by applying non-toxic organic coatings known as lacquers in conjunction with tin plating. These lacquers are usually applied to the sheet of tin plate before being made into the can linings. The lacquers are of two types – acid resistant (R-enamel) and sulphur-resistant (C-enamel). R-enamel lined cans are used for packing fruits of the acid group having soluble colouring matter (e.g. strawberry, red plums, coloured grapes). Fruits with insoluble colouring matter (peaches, pineapples, apricots, grapefruits) are packed in plain cans. The C-enamel cans are used for low and medium acid foods like peas, corn, lima beans and red kidney beans to prevent discolouration of the contents and staining of the inside of the container. The tin and enamel coating requirements for tin cans for some foods are given in Table 10.1.

d. Manufacture of tin can – An important characteristic of the tin-plate can is its ability to offer a hermetic seal capable of withstanding the pressures of retorting. This rugged property is the result of the way in which the can is manufactured. The essential unit operations in the manufacture of tin can are: –

i. Cutting body blanks – Tin plate is cut to proper size with a trimming and slitting machine, called the gang slitter. Duplex slitters are employed for high-speed production. These cut the sheets in one direction and the strips are automatically fed to the second section where these are cut transversely to the correct can size.

Table 10.1 **Tin and enamel coating requirements for different foods.**

Type of food	Coded specifications: Can body	Coded specifications: Can top/ bottom
Prepared pulses with or without meat	F24 bl or E2 ila	E2 dola
Carrots, spinach, tomatoes, low acid foods	E2 ila or E4 ila	E2 dola or E4 dola
Cauliflower. Mushrooms	F24 bl or E2 ila	E2 dola
Berries and pit fruits	E2 sla or E4 ila	E2 sla or E4 ila
Apples, peas and apple sauce	F24 bl or E4 ila E2 sla	E4 dola or E2 sla
Mixed vegetables	E2 ila	E2 dola

Source: Heiss, R. (1970).

*Codes: E = Electrolytic tinplate; F = Dip-coated tinplate; bl = Unlacquered; dola = inside and outside enamelled; ila = inside enamelled; sla = additional spray coating on the inside.

The numbers superseding the letters E and F represent minimum and maximum amounts of tin g/m^2 as follows: 2 = 10.5 – 11.2; 3 = 15.7 – 16.8; 4 = 21 – 24.

ii. Notching of body blanks – Each body blank is notched at the four corners to enable formation of smooth edges when the side seam is made. In the absence of notching, there is a danger of leakage after the double seam is made.

iii. Lock seaming – The flat can body is passed through an edging machine where hooks are formed. The edges are hooked together and a uniform union is brought about by a hammer. The lap seam is passed through a layer of molten solder ensuring a perfect seal.

iv. Flanging – The body blank is passed through a flanger, which turns the edges outwards to form flanges that receive the lid.

v. Forming can ends (lids) – Tin plate is cut into strips of appropriate size and passed through a 'stamping machine' to cut the lids. This machine also forms concentric ridges and depressions that give rigidity to the ends. The lids are passed through a curling machine that bends down the ends of the lids inwards.

vi. Gasket laying – The curled edge of the can ends is lined with a water emulsion of rubber or plastic gum. This ensures hermetical sealing of the lids to the body.

vii. Sealing the ends – The lid is placed on the flanged can. In a double seaming machine the first pair of rollers bends the edges of the lid and the can so that they touch each other. Second pair of the rollers tightly compresses the folded flanges together to bring about a perfect seal. Pressure is exerted by the same rollers against the ends of the can body, forcing the gasket tightly against the lid end (Fig. 4.3).

10.3.2 Flexible Metal Containers

Aluminium is a metal of low tensile strength, but at thickness of 2.5 to 5 mm it has been successfully made into small cans with sufficient strength to withstand heat processing. Aluminium and its alloys with manganese or magnesium offer commercial alternatives to the tin can. Lacquered aluminium cans are currently used for packaging sardines in sauces and oil, meat, fish paste and fruit juices.

The aluminium cans cannot be soldered as readily as the tin can, hence aluminium can making procedure involves drawing or impact extrusion. When used for acid foods, they must additionally be protected by lacquering. The advantages and disadvantages of aluminium cans are summarized in Table 10.2.

Aluminium in the form of foil is the only metal used commercially as a flexible food packaging material. Its foil is manufactured by rolling slabs of pure aluminium to a thickness of about 0.009 mm to 0.012 mm (3/8 to ½ mil). This foil has improved tensile strength, but is usually brittle for general use. By annealing, the foils are softened and made more pliable. Annealed foils have found limited use in packaging products like chocolate and butter. Notwithstanding its sensitivity to corrosion that can easily be reduced by lacquering and its limiting mechanical properties, aluminium foils have several favourable properties. These include impermeability to water, water vapours, gases, oil and radiation at thickness between 0.009 and 0.012 mm, provided closure points are properly sealed. Aluminium foil can also be printed upon and decorated due to its non–resilience. It is particularly resistant to attack by many species of insects. However, owing to its poor mechanical strength, aluminium foil is more often used in combination with other materials (see Laminates and Multilayer Materials, Section 10.7).

Table 10.2 Some basic advantages and disadvantages of aluminium cans

Advantages	Disadvantages
Cans are easy to open	Usually more expensive than tin cans
Cans can be heated on open fire and hot plate	Manufactured cans have a high volume and are non-collapsible
Do not impart flavour or colour to food	Sizes and capacities are limited
Good resistance to external corrosion	Weaker than tin plate can and can easily be dented
Free from internal pitting corrosion	Acid foods need cans properly lacquered
Equipment for manufacture are simple	Special autoclaves are usually required for sterilization
Lines for small output are available	Need different body making facilities from tin cans
Empty cans will not rust and have a reuse or scrap value	More care is needed in forming the seam

10.4 GLASS

Glass was indisputably the packaging material for most foods a few decades ago. Now a keener competition exists between glass and other packaging materials. Although heavier than most other packaging materials, glass containers are still popular for food packaging for a number of reasons: -

a. They are inert.
b. Generally transparent.
c. Adaptable to high-speed filling.
d. Are comparatively cheap and reusable.
e. Can resist high internal pressures and vertical loads.
f. Deformation can only occur destructively.

10.4.1 Manufacture of Glass Container

Commercial container glass is manufactured by heating, at about 1500°C to a molten state, a mixture of silicon dioxide (74%), calcium oxide (7%), sodium oxide (18%), magnesium oxide (1%), and traces of ferrous oxide and manganese oxide. This is poured into moulds in which compressed air is passed from the neck side of the container. This presses the liquid glass towards the sides and forms particular shape of the mould. After the glass container is formed it is submitted to an annealing in curing ovens. In this process the container is heated to about 540°C in the beginning and about 260°C at the end. This markedly improves container toughness, reduces and advantageously distributes residual stresses and strains.

10.4.2 Glass Container Seal

From a safety point of view, the seal is as important as the container itself. Effective sealing can be obtained by using ordinary stoppers, roll–on pilfer proof caps, aluminium caps or metal screw caps for normal pressure seals. Crown corks, alka caps or external screw caps are employed for pressure seals. For successful use of any of these, tolerance specifications for each type of closure must be met at the bottle design stage.

When adequately sealed, glass containers have no measurable transmission to moisture, gases and odours. These can be made selectively permeable or impermeable to radiation of specific wavelength by incorporating special compounds at the manufacturing stage.

10.4.3 Glass Fracture

Brittleness is the most limiting property of glass which is associated with characteristic sudden failure from tensile stresses. Good glass manufacturing practice includes the selection of optimum raw materials, architecturally designed moulds and annealing and cooling temperatures. These greatly improve the glass strength.

Glass containers must be handled with great care to reduce surface scratching, since it is a very important component of bottle ruggedness. Tendency to glass fracture is increased by surface scratches. To reduce the incidence of surface scratches and hence the number of breakages during handling, glass containers are coated with waxes and silicones prior to leaving the annealing chambers. This imparts lubricity to their surfaces. This fact must always be emphasized to bottle handlers such as transporters, washers and fillers.

The most common internal fracture foci for glass containers are caused by either thermal shock or impact. Thermal shock can be reduced by avoiding large and sudden temperature differentials in parts of the bottle during handling. The thickness of bottles must provide adequate strength to withstand internal pressure. It should not be so

thick as to create large temperature differentials between the two surfaces of the bottle during heat processing.

10.4.4 Returnable and Non-returnable Bottles

Glass containers are manufactured either for one time (one-way bottles) or repeated use (returnable bottles). Returnable glass containers are usually thicker and have more effective protective coating on their exterior surface than one-way containers. These extras compensate for the effects of longer periods of handling abuse and pressures from both stacking and bottle contents. The use of returnable bottles is popular in developing countries for carbonated beverages. These bottles are considered cheap packages for low cost liquid products of relatively short life span. However, when the cost of disposing littered one-way bottles from the environment is put in perspective, the choice of using returnable bottles may prove even more appropriate for developing countries.

10.5 FLEXIBLE AND RIGID CELLULOSICS AND PLASTICS

Cellulose based compounds and plastics in flexible, semi-rigid or rigid forms are important packaging materials (Fig. 10.3). They are formed from basic organic molecules based on cellulose in case of cellulosics and various other organic compounds in case of plastics. These molecules when induced to polymerise, form polymers of peculiar packaging characteristics. Polymers made from one type of basic chemical unit are known as `homopolymers', while those formed from a mixture of two or more basic chemical units are known as `copolymers'.

Fig 10.3 Rigid metal container (left) and flexible plastic container (right). Courtesy: Lever Brothers Nigeria Ltd.

Among the important cellulosics used as food packaging materials are cellophane (regenerated cellulose) and cellulose acetate. The plastics employed for food packaging are: polyamide (nylon), polyester resin (Mylar™, Scotch Pak™), polyethylene resin, polypropylene resin, polystyrene resin, polyvinyl chloride, polyvinylidine chloride and rubber hydrochloride. By forming polymers from mixtures of two or more of the basic plastic materials, copolymers such as polyethylene vinyl acetate, polypropylene ethylene, propylene vinyl chloride, polyvinylidine vinyl (seran, cryovac) and ethylene acrylic acid have emerged. These copolymers exhibit improved general properties for specific packaging requirements.

By increasing the thickness of plastic films, it is possible to produce semi-rigid and rigid bags, bottles and other containers. Usually, the rigid containers are produced by injection or blow moulding or by thermoforming semi-finished plastic sheeting (Fig. 10.4).

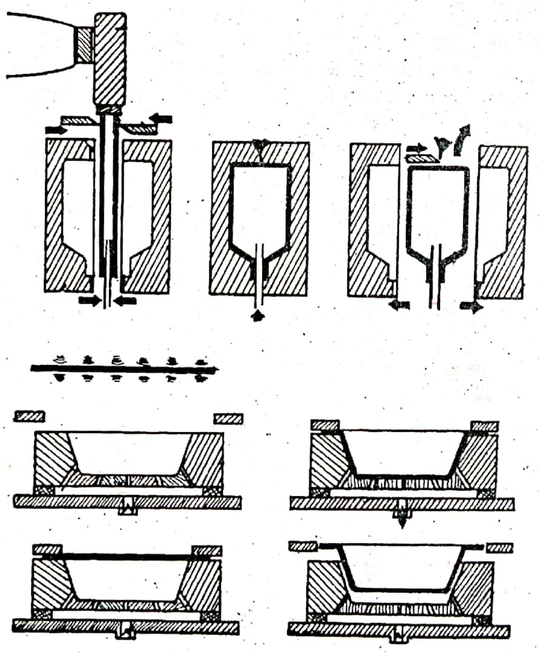

Fig. 10.4 **Steps in blow moulding of bottles (top) and thermoforming (bottom).**

Low-density polyethylene of thickness 0.03 – 0.18 mm (1 – 6 mil) can be made into semi-rigid bags and sacks strong enough to withstand pressure generated by 10 kg or more of product. Such sacks are excellent for packaging dehydrated foods such as sugar and skim milk, which must be kept dry. High-density polyethylenes, which have higher strength than low-density polyethylene, are suitable for the manufacture of rigid bottles. However, because of their high gas permeability and affinity for fats, such bottles cannot protect loss of aroma and fat from foods. They are mainly employed for packaging of potable water, fruit juice concentrates and syrups. Rigid bottles made from polyvinylidine chloride (PVDC) are more resistant to fat leaching and flavour loss. These are, therefore, popular for packaging fatty foods that must be protected from flavour loss or gain. Rigid bottles can also be made from polystyrene but these are not popular for packaging food.

10.6 FLEXIBLE AND RIGID PAPER PRODUCTS

Paper is a very important packing and packaging material owing to its low cost, low weight and adaptability to various treatments, which improve their functionality. Paper products for packaging include wrapping paper, bags, pouches and cartons.

The basic raw material for papermaking is cellulose. This is obtained from wood pulp, straw, cotton linters, hemp, flax, jute and others either as primary or second hand raw materials. The isolation of cellulose fibres from various sources entails different processes. For example, cotton rags of short fibre length are cooked in rotary boilers containing sodium hydroxide, lime and mixtures of lime and sodium carbonate. Wood or annual plants are treated with sulphites and sulphates to produce pulp. By the use of special chemical and mechanical treatment, paper of particular strength, water and fat resistance and glossiness can be produced (Table 10.3). Paper for packing and packaging can be further improved functionally by coating or laminating to either paper or other materials.

10.7 LAMINATES AND MULTILAYER MATERIALS

The packaging properties of rigid and flexible metals, glass, paper, cellulosic and plastic films reveal that no single packaging material exhibits all the desirable attributes of an ideal package. It is common today to find composite packages made of concentric layers of two or more basic packaging materials such as paper, foil, and film glued together (multiplayer). Composite packages or laminates, as these packages are called, combine the properties of each basic packaging material from which they are made. By combining materials with complimentary packaging characteristics, the package designer tailors-in desired properties to meet the requirements of almost any food product.

Table 10.3 Types of papers used in food packaging

Type	Description
Kraft paper	Ordinary paper made from sulphate pulp with good strength but with poor wet strength and grease-proofing ability.
Pouch paper	Ordinary paper usually made from sulphite pulp, usually bleached and used for pouch paper bags
Grease proof	Paper produced by high speed beating of pulp and water to obtain improved grease proofing properties
Glassine	Grease proof that has been polished by passing through a super calendar
Vegetable parchment	Paper of good strength and grease proofing properties produced by low speed beating of pulp and water followed by subsequent treatment with sulphuric acid
Tissue paper	Soft and extremely flexible paper with excessive high gas permeability
Crape paper	Paper of improved elongation produced by craping in craping machine.

Sometimes a basic packaging material can be made more versatile by a simply coating with a clear or pigmented lacquer of a water dispersion of an organic polymer or plastic resin forming laminates. Regenerated cellulose films when coated with different amounts of nitro-cellulose are made suitable for packaging baked foods, fruits, vegetables and meat. The amount of nitro-cellulose coating modifies the water vapour transmission rate of the film to suit the particular product. Fruits and vegetables normally require a thinner coating than backed goods, since they have a higher respiratory rate, therefore need a package with more water vapour transmission. For fresh packaged meat, it is important to sustain positive oxygen movement into the package since this is essential in meat colour stability. This is achieved by coating one side of the regenerated cellulose film with nitro-cellulose. As long as the coated side of the film is in contact with the meat surface to ensure some wetting of the overlying cellulose layer, oxygen diffusion into the package

is enhanced. This is so because dry regenerated cellulose films have considerably low gas transmission ability, which increases on wetting.

10.7.1 Retort Pouch

Retort pouch is especially made to withstand thermal processing. It is produced from a flexible laminate made with 2 to 4 layers, which typically include polyester, aluminium foil and polyolefin or polypropylene. All layers must be capable of being retorted. Typical materials, from outside to inside, include:

a. 2-ply: 12 µm nylon or polyester/70 µm polyolefin;

b. 3-ply: 12 µm polyester/12 µm aluminum/70 µm polyolefin

Each layer has a specific function: The outside layer provides strength, printability and scuff resistance. It also serves as a barrier to gas, moisture and light. The middle layer of aluminium foil gives excellent water vapour, gas and light barrier properties. It has superb heat transfer characteristics. The inner layer provides heat seal integrity, compatibility with food product and strength. Polyester and polypropylene can be processed at up to 135°C.

The advantages in using retort pouches over other packs are: -

a. Shorter process time than a similar size of metal or glass container due to thin cross section.
b. Improved product quality due to less overcooking.
c. No interaction of product and container.
d. Processing of unique food products due to facility of vacuum sealing.
e. Savings in storage and transportation due to reduced weight and space compared to rigid containers.
f. Convenience in cooking and opening as boiling-bag applications.

10.8 PROTECTIVE PACKAGING IN TROPICAL ENVIRONMENTS

The principal function of packaging in any environment is to protect the packaged product against contamination and all types of deterioration and spoilage during its useful storage life. Tropical environments are unique in having high relative humidity and high, usually fluctuating, ambient temperatures. These conditions encourage growth of insects and microorganisms, and accelerate physico-chemical deterioration and spoilage of foods. The tropical and subtropical climatic belt is the location of many developing countries.

In considering packaging of food in tropical and subtropical regions, adequate attention must be given to the peculiar environmental and economic situations in these areas. In principle, it is possible to formulate several alternative packaging systems for food products based on the knowledge of the composition, stability and expected life expectancy of the product and characteristics of the available packaging materials. This principle is applied in the selection of packaging materials for special food items.

The level of water vapour tightness, oxygen tightness, odour and gas proofness for any particular product depends on the nature of the storage environment and the turnover time of the product. For most stringent requirements against water vapour, gas and odour infiltration, one must resort to either metal containers, hermetically sealed glass jars or composite heat sealable aluminium based laminates. For protection against light, pigmented wrappers and cartons perform adequately.

Most plastic films and impregnated papers contribute sufficient wet strength to packages, while drip proofness is usually achieved by the use of either glass, rigid metal containers or plastic films of sufficient gauge. For grease proofness, pin hole-free aluminium foil, plain regenerated cellulose film, high quality glassine or films of polyvinyl chloride, polyvinylidine chloride and polyester are usually considered effective.

10.9 FOOD LABELLING

Label means any tag, brand, mark, pictorial or other descriptive matter, written, printed, stenciled, marked, embossed or impressed on, or attached to, a container of food. Labelling includes any written, printed or graphic matter that is present on the label. According to the Codex Alimentarius, following information is considered to be of a mandatory nature and, as such, must appear on the label of prepackaged foods: -

a. The name of the food.
b. List of ingredients.
c. Net contents and drained weight.
d. Name and address of the manufacturer.
e. Lot identification.
f. Date marking and storage instructions.
g. Instructions for use.

Nutrition labeling is not mandatory but is of advisory nature. It provides information to the consumer concerning the nutritional profile of the food.

"CHOOSE A JOB YOU LOVE, AND YOU WILL NEVER HAVE TO WORK A DAY IN YOUR LIFE".