Paper No.: 02

Paper Title: The Principles of the Food Processing & Preservation

Module No. : 04

Module Title: Principles of Food Processing and Preservation

4.0 Introduction

The main reasons for food preservation are to overcome inappropriate planning in agriculture, produce value-added products, and provide variation in diet. The agricultural industry produces raw food materials in different sectors. Inadequate management or improper planning in agricultural production can be overcome by avoiding inappropriate areas, times, and amounts of raw food materials as well as by increasing storage life using simple methods of preservation. Value-added food products can give better-quality foods in terms of improved nutritional, functional, convenience, and sensory properties. In food preservation, the important points that need to be considered are

- The desired level of quality
- The preservation length
- The group for whom the products are preserved

4.1 Preservation of foods

After storage of a preserved food for a certain period, one or more of its quality attributes may reach an undesirable state. Quality is an illusive, ever-changing concept. In general, it is defined as the degree of fitness for use or the condition indicated by the satisfaction level of consumers. When food has deteriorated to such an extent that it is considered unsuitable for consumption, it is said to have reached the end of its shelf life. The product quality attributes can be quite varied, such as appearance, sensory, or microbial characteristics. Loss of quality is highly dependent on types of food and composition, formulation (for manufactured foods), packaging, and storage conditions. Quality loss can be minimized at any stage of food harvesting, processing, distribution, and storage. The product quality can be defined using many factors, including appearance, yield, eating characteristics, and microbial characteristics, but ultimately the final use must provide a pleasurable experience for the consumer. The various stages of food production, manufacture, storage, distribution, and sale are shown in Figure 1.

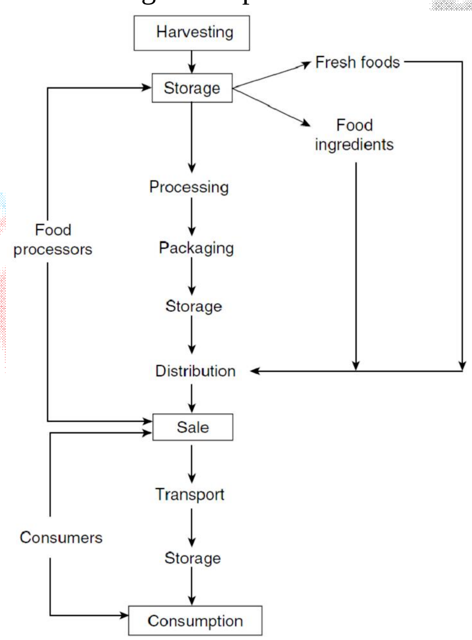

Figure.1: Various stages of food production, manufacturing, storage, distribution & sale

Quality loss can be minimized at any stage and thus quality depends on the overall control of the processing chain. The major quality-loss mechanisms and consequences are shown in Table.1 and Figure.2.

Microbiological	Enzymatic	Chemical	Physical	Mechanical
Microorganism growth	Browning	Color loss	Collapse	Bruising due to vibration
Off-flavor	Color change	Flavor loss	Controlled release	Cracking
Toxin production	Off-flavor	Nonenzymatic browning	Crystallization	Damage due to pressure
		Nutrient loss	Flavor encapsulation	
		Oxidation–reduction	Phase changes	
		Rancidity	Recrystallization	
			Shrinkage	
			Transport of component	

Table.1: Major quality loss mechanisms

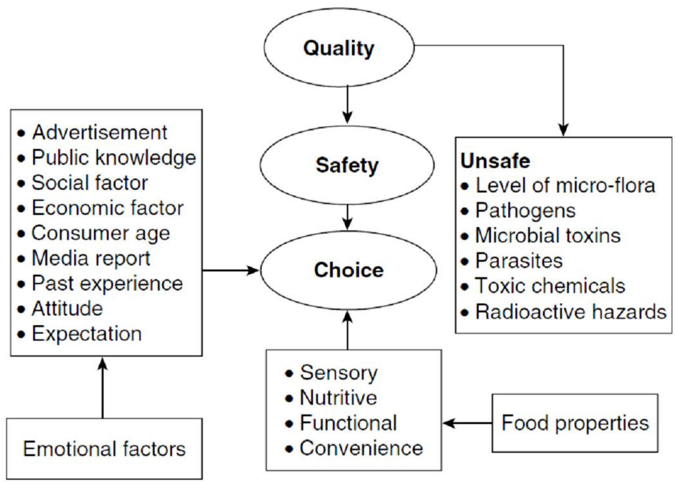

Figure.2: Factors affecting food quality, safety and choice

4.2 Causes of Deterioration

Mechanical, physical, chemical, and microbial effects are the leading causes of food deterioration and spoilage. Damage can start at the initial point by mishandling of foods during harvesting, processing, and distribution; this may lead to ultimate reduction of shelf life. Other examples of deterioration can be listed as follows: (i) bruising of fruits and vegetables during harvesting and postharvest handing, leading to the development of rot, (ii) tuberous and leafy vegetables lose water when kept in atmospheres with low humidity and, subsequently, wilt, and (iii) dried foods kept in high humidity may pick up moisture and become soggy. The four sources of microbial contaminants are soil, water, air, and animals (insects, rodents, and humans) (Table.2). In preservation, each component factor needs to be controlled or maintained to a desired level.

1. Microorganisms
   a. Fungi: mold and yeast
   b. Bacteria
   c. Phages
   d. Protozoa
2. Insects and mites
   a. Directly by eating (infestation)
   b. Indirectly by spreading diseases (fruitfly, housefly)
3. Rodents
   a. Directly by consuming food
   b. Indirectly by spreading diseases

Table.2: Organisms that spoil food

During storage and distribution, foods are exposed to a wide range of environmental conditions. Environmental factors such as pressure, temperature, humidity, oxygen, and light can trigger several reactions that may lead to food degradation. Mechanical damage (e.g., bruises and wounds) is conducive to spoilage, and it frequently causes further chemical and microbial deterioration.

Peels, skins, and shells constitute natural protection against this kind of spoilage. Shriveling occurs due to the loss of water from harvested fruits and vegetables. Each microorganism has (i) an optimum temperature at which it grows best, (ii) a minimum temperature below which growth no longer takes place, and (iii) a maximum temperature above which all development is suppressed. Bacteria that grow particularly well at low temperatures are called *psychrophilic* (*cryophilic*) or low-temperature organisms. Bacteria with an optimum temperature of 20°Cï 45°C are *mesophilic*, and those with an optimum temperature above 45°C are *thermophilic*. Microbial growth in foods results in food spoilage with the development of undesirable sensory characteristics, and in certain cases the food may become unsafe for consumption. Microorganisms have the ability to multiply at high rates when favorable conditions are present. Prior to harvest, fruits and vegetables generally have good defense mechanisms against microbial attack; however, after separation from the plant, they can easily succumb to microbial proliferation.

The presence of unsaturated fatty acids in foods is a prime reason for the development of rancidity during storage as long as oxygen is available. While development of off-flavors is markedly noticeable in rancid foods, the generation of free radicals during the autocatalytic process leads to other undesirable reactions, for example, loss of vitamins, alteration of color, and degradation of proteins. The presence of oxygen in the immediate vicinity of food leads to increased rates of oxidation. Similarly, water plays an important role; lipid oxidation occurs at high rates at very low water activities. Some chemical reactions are induced by light, such as loss of vitamins and browning of meats. Nonenzymatic browning is a major cause of quality change and degradation of the nutritional content of many foods. This type of browning reaction occurs due to the interaction between reducing sugars and amino acids, resulting in the loss of protein solubility, darkening of lightly colored dried products, and development of bitter flavors. Environmental factors such as temperature, water activity, and pH have an influence on nonenzymatic browning.

4.3 Principles of food preservation

Based on the mode of action, the major food preservation techniques can be categorized as
(1) Slowing down or inhibiting chemical deterioration and microbial growth,
(2) Directly inactivating bacteria, yeasts, molds, or enzymes, and
(3) Avoiding recontamination before and after processing.

A number of techniques or methods from the above categories are shown in Figure. 3.

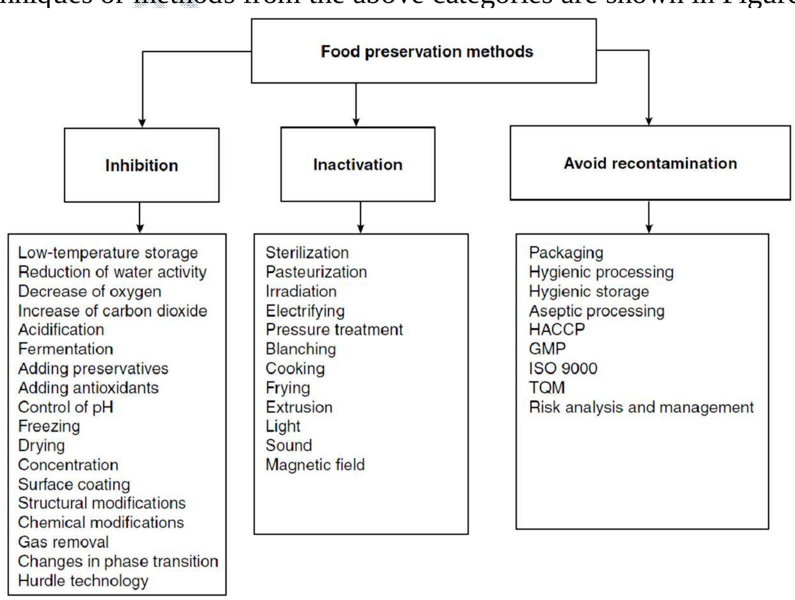

Figure.3: Major food preservation techniques

A good method of food preservation is one that slows down or prevents altogether the action of the agents of spoilage. Also, during the process of food preservation, the food should not be damaged. In order to achieve this, certain basic methods were applied on different types of foods. For example in earlier days, in very cold weather condition, ice was used to preserve foods. Thus, very low temperature became an efficient method for preventing food spoilage. The principles of food preservation are:

- **Removal of micro-organisms or inactivating them:** This is done by removing air, water (moisture), lowering or increasing temperature, increasing the concentration of salt or sugar or acid in foods. If you want to preserve green leafy vegetables, you have to remove the water from the leaves so that micro organisms cannot survive. You do this by drying the green leaves till all the moisture evaporates.
- **Inactivating enzymes:** Enzymes found in foods can be inactivated by changing their conditions such as temperature and moisture, when you preserve peas, one of the methods of preservations is to put them for a few minutes in boiling water. This method also known as blanching inactivates enzymes and thus, helps in preserving the food.
- **Removal of insects, worms and rats:** By storing foods in dry, air tight containers the insects, worms or rats are prevented from destroying it.

While the currently used preservation procedures continue in one or more of these three ways, there have recently been great efforts to improve the quality of food products principally to meet the requirements of consumers through the avoidance of extreme use of any single technique. Preservation starts when the harvested foods are separated from the medium of immediate growth (plant, soil, or water) or meat from the animal after slaughter, or milk from normal secretion of mammalian glands. Postharvest technology is concerned with handling, preservation, and storage of harvested foods, and maintaining its original integrity, freshness, and quality. The methods of preservation depend on the origin of foods particularly whether they are of plant or animal origin. Postharvest handling of foods of plant origin includes efficient control of environmental atmosphere, such as humidity, gas composition, and temperature, and implementing an adequate packing, storage, and transport system. Physical treatments usually used are curing, pre-cooling, temperature treatments, cleaning, and waxing, whereas chemical treatments are disinfection, fumigation, and dipping. Chemical disinfectants vary in their ability to kill microorganisms. Several chemicals are utilized, such as chlorine, chlorine dioxide, hydrogen peroxide, ozone, peroxyacetic acid, bromine, iodine, trisodium phosphate, and quaternary ammonium compounds. Although fumigants are not strictly preservatives, they are used for insect control. Methyl bromide is one of the fumigants used, but it has the potential to damage atmospheric ozone and is being phased out. There is a need for development of new environmentally safe methods of fumigation.

4.3.1 Inhibition

The methods based on inhibition include those that rely on control of the environment (e.g., temperature control), those that result from particular methods of processing (e.g., microstructural control), and those that depend on the intrinsic properties built into particular foods (e.g., control by the adjustment of water activity or pH value. The danger zone for microbial growth is considered to be between 5°C and 60°C; thus chilling and storing at a temperature below 5°C is one of the most popular methods of food preservation.

Use of Chemicals: The use of chemicals in foods is a well-known method of food preservation. Wide varieties of chemicals or additives are used in food preservations to control pH, as antimicrobes and antioxidants, and to provide food functionality as well as preservation action. Some additives are entirely synthetic (not found in nature), such as phenolic antioxidant tertiary butylhydroquinone (TBHQ), and others are extracted from natural sources, such as vitamin E. Irrespective of origin, food additives must accomplish some desired function in the food to which they are added, and they must be safe to consume under the intended conditions of use. Many legally permitted preservatives in foods are organic acids and esters, including sulfites, nitrites, acetic acid, citric acid, lactic acid, sorbic acid, benzoic acid, sodium diacetate, sodium benzoate, methyl paraben, ethyl paraben, propyl paraben, and sodium propionate. When a weak acid is dissolved in water, equilibrium is established between un dissociated acid molecules and charged anions, the proportion of un dissociated acid increasing with decreasing pH. There are several limitations to the value of organic acids as microbial inhibitors in foods:

- They are usually ineffective when initial levels of microorganisms are high.
- Many microorganisms use organic acids as metabolizable carbon sources.
- There is inherent variability in resistance of individual strains.
- The degree of resistance may also depend on the conditions.

Controls of Water and Structure: Many physical modifications are made in ingredients or foods during preservation. Such modifications can also improve the sensory, nutritional, and functional properties of foods. Changes experienced by foods during processing include glass formation, crystallization, caking, cracking, stickiness, oxidation, gelatinization, pore formation, and collapse. Through precise knowledge and understanding of such modifications, one can develop safe, high-quality foods for consumption. Water is an important constituent of all foods. The minimum water activity is the limit below which a microorganism or group of microorganisms can no longer reproduce. For most foods, this is in the water activity range of 0.6ï 0.7. Pathogenic bacteria cannot grow below a water activity of 0.85ï 0.86, whereas yeast and molds are more tolerant of a reduced water activity of 0.80, but usually no growth occurs below a water activity of about 0.62. The critical limits of water activity may also be shifted to higher or lower levels by other factors, such as pH, salt, antimicrobial agents, heat treatment, and temperature to some extent. Removing water, adding solutes, or change of soluteï water interactions can reduce the water activity of a food.

Control of Atmosphere: Packaging techniques based on altered gas compositions have a long history. The respiratory activity of the various plant products generates a low-oxygen and high-carbon dioxide atmosphere, which retards the ripening of fruit. Modified-atmosphere packaging is a preservation technique that may further minimize the physiological and microbial decay of perishable produce by keeping them in an atmosphere that is different from the normal composition of air. The gas composition and method of this technique depends on the types of produce and purposes. There are different ways of maintaining a modified atmosphere. In modified atmosphere packaging (termed ñpassive atmosphereò), the gas composition within the package is not monitored or adjusted. In ñcontrolled atmosphere packaging,ò the altered gas composition inside the packaging is monitored and maintained at a preset level by means of scrubbers and the inlet of gases. Active packaging can provide a solution by adding materials that absorb or release a specific compound in the gas phase. Compounds that can be absorbed are carbon dioxide, oxygen, water vapor, ethylene, or volatiles that influence taste and aroma. Vacuum and modified-humidity packaging contain a changed atmosphere around the product. Although this technique was initially developed to extend the shelf life of fresh products, it is now extended to minimally processed foods from plant and animal sources, and also to dried foods.

4.3.2 Inactivation

Use of Heat Energy: Earlier, mostly heat was used for inactivation. Thermal inactivation is still the most widely used process of food preservation. The advantages of using heat for food preservation are

- Heat is safe and chemical-free
- It provides tender cooked flavors and taste
- The majority of spoilage microorganisms are heat labile
- Thermally processed foods, when packed in sterile containers, have a very long shelf life

The main disadvantages of using heat are (i) overcooking may lead to textural disintegration and an undesirable cooked flavor, and (ii) nutritional deterioration results from high temperature processing. Heat treatment processes include mainly pasteurization, sterilization, cooking, extrusion, and frying. Recently, more electrotechnologies have been used and this will expand further in the future.

Use of High Pressure and Ultrasound: High-quality fresh foods are very popular, so consequently there is a demand for less extreme treatments and fewer additives. High-pressure hydrostatic technology gained attention for its novelty and non-thermal preservation effect. Ultrasound is sound energy with a frequency range that covers the region from the upper limit of human hearing, which is generally considered to be 20 kHz. The two applications of ultrasound in foods are (i) characterizing a food material or process, such as estimation of chemical composition, measurements of physical properties, nondestructive testing of quality attributes, and monitoring food processing, and (ii) direct use in food preservation or processing. The beneficial or deteriorative use of ultrasound depends on its chemical, mechanical, or physical effects on the process or products.

Use of Electricity: Many different forms of electrical energy are used in food preservation, e.g., ohmic heating, microwave heating, low electric field stimulation, high-voltage arc discharge, and high-intensity pulsed electric field. *Ohmic heating* is one of the earliest forms of electricity applied to food pasteurization. This method relies on the heat generated in food products as a result of electrical resistance when an electric current is passed through them. *Microwave heating* has been extensively applied in everyday households and the food industry, but the low penetration depth of microwaves into solid food causes thermal non uniformity. *Low electric field* stimulation has been explored as a method of bacterial control in meat. The plasma membranes of cells become permeable to small molecules after being exposed to an electric field; permeation then causes swelling and the eventual rupture of the cell membrane. The reversible or irreversible rupture (or electroporation) of a cell wall membrane depends on factors such as intensity of the electric field, number of pulses, and duration of pulses. This new electro-heating could be used to develop new products with diversified functionality.

Use of Radiation: Ionization radiation interacts with an irradiated material by transferring energy to electrons and ionizing molecules by creating positive and negative ions. The irradiation process involves exposing the foods, either prepackaged or in bulk, to a predetermined level of ionization radiation. Irradiation has wide scope in food disinfection, shelf life extension, decontamination, and product quality improvement. Although it has high potential, there is concern on legal aspects and safety issues, and consumer attitude toward this technology. Ultraviolet (UV) radiation has long been known to be the major factor in the antibacterial action of sunlight. It is mainly used in sterilizing air and thin liquid films due to its low penetration depth. Pulsed light is a sterilization method in applications where light can access all the important volume and surfaces. Examples include packaging materials, surfaces, transmissive materials (such as air, water, and many solutions), and many pharmaceuticals or medical products. The white light pulse is generated by electrically ionizing a xenon gas-filled lamp for a few hundred millionths of a second with a high-power, high-voltage pulse. In many cases, it would be very difficult to make a clear distinction between inhibition and inactivation.

Use of Magnetic Field: Magnetism is a phenomenon by which materials exert an attractive or repulsive force on other materials. The origin of magnetism lies in the orbital and spin motions of electrons and how the electrons interact with each other. Magnetic fields have potential in pasteurization, sterilization, and enhancing other factors beneficial to processing in food preservation.

4.3.3 Avoid Recontamination (Indirect Approach)

In addition to the direct approach, other measures such as packaging and quality management tools need to be implemented in the preservation process to avoid contamination or recontamination. Although these measures are not preservation techniques, they play an important role in producing high-quality safe food. With respect to the procedures that restrict the access of microorganisms to foods, the employment of aseptic packaging techniques for thermally processed foods has expanded greatly in recent years both in the numbers of applications and in the numbers of alternative techniques that are commonly available. From skins, leaves, and bark, tremendous progress has been made in the development of diversified packaging materials and equipments. Packaging performs three main functions. The first is to control the local environmental conditions to enhance storage life. The second is the display, i.e., preservation of the product in an attractive manner to the potential buyer. The third function is to protect the product during transit to the consumer. The new concept of active or life packaging materials allows one-way transfer of gases away from the product or the absorption of gases detrimental to the product, antimicrobials in packaging, release of preservatives from controlled-release surfaces, oxygen scavengers, carbon dioxide generators, absorbers or scavengers of odors, absorption of selected wavelengths of light, and there are capabilities for controlled automatic switching. Another concept of edible or biodegradable packaging has also been evolved for environmental reasons. Processing and packaging can be integrated to improve efficiency.

4.4 Conclusion

The major driving forces in the development and modification of food processing are the desire to reduce the extent of processing, i.e., the demand for *lightly processed* or *fresh-like,* organic, and natural foods; the desire to maximize automation, control, and efficiency; and the desire to minimize cost, and the need to respond to an ever-increasing strict regulations concerning environmental impact of various processes. The factors that should be considered before selecting a preservation process are the desired quality of the products, the economics of the process, and the environmental impact of the methods. The ultimate success of the food industry lies in the timely adoption and efficient implementation of the emerging new technologies to satisfy the present and the future demands of the consumer.