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Introductory Chapter: Food Processing, Preservation, and Packaging – A Brief Overview

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1. Introduction

Food processing, preservation, and packaging are important to increase food availability for human consumption. Food processing includes mechanical, chemical, and thermal methods to process foods to increase their palatability and shelf life. Food processing transforms raw ingredients into food or other intermediate products, and preservation is the process of handling and treating food to control its spoilage by stopping the attack and growth of foodborne diseases causing microbes, avoiding oxidation of fats (rancidity), and maintaining the nutritional value, texture, and flavor of the food [1]. According to Saini et al. [2], the chemicals, microbes, and enzymes present in the food itself result in food spoilage if not processed and preserved. Besides, food and its products must be transported from one place to another. During transit, there are chances to deteriorate the food, loss or decrease in morphological properties, and reduction in the nutritional value of the food. Therefore, it is important to make efforts for food processing and preservation for longer shelf life, stability in quality, maintaining morphological properties, and no change in taste [1].

Various traditional and modern methods were developed, considering the importance of food preservation to reduce post-harvest losses and the chances of food poisoning and other diseases. Commonly used food preservation methods are refrigeration, canning, irradiation, drying, salting, smoking, and fermentation, which help improve the shelf stability of foods such as meats, fruits, vegetables, and fish-based products. Many traditional methods, such as preserving fruits by changing them into jams, had lower energy input and carbon footprint than modern techniques [3]. Some traditional methods involve boiling fruits to kill microbes and decrease the moisture contents, adding enough sugar to prevent the regrowth of microbes, and sealing them in an airtight jar to prevent contamination [3]. Sugaring causes the jam much hypertonic and makes it hard for microbes to survive. Various research areas of food preservation include preventing the growth of bacteria, fungi, or other microorganisms and preventing chemical reactions, such as retarding the oxidation of fats, thus extending the shelf life of food products. In addition, packaging research focuses on improving the shelf life of convenient, ready-to-eat, tasty, and mild processed food products. Currently novel biodegradable packaging materials are gaining importance in addressing the environmental pollution caused by fossil-based packaging materials. This chapter provides an overview of food processing, preservation, and packaging technologies used to develop new products and improve their shelf life.

2. Food spoilage

By definition, food spoilage is the process that renders food unfit for human consumption [4]. Various factors, such as contamination by microorganisms, insect infestation, or enzyme degradation, cause food spoilage [5]. In addition, physical changes, such as tearing plant or animal tissues, and chemical changes, such as oxidation of certain constituents of food, cause food spoilage. Foods from plant or animal sources degrade after harvest and slaughter due to enzymes in the plant cells and animal tissues and mechanical damage caused during harvesting and post-harvest handling. The enzymes in the foods break down due to chemical reactions catalyzed due to the storage environment causing food spoilage or degradation—the changes or degradation results in off-flavors, textural changes, and loss of nutrients [6]. The common food spoilage bacteria are *Lactobacillus*, yeasts, *Saccharomyces*, and molds (e.g., *Rhizopus*). In addition, bacteria and fungi (yeasts and molds) cause food spoilage and foodborne illnesses. In addition, microorganisms may contaminate foods during harvest, storage, processing, distribution, handling, or preparation. Enzymes that cause the degradation of the food quality are listed in **Table 1** [7].

Enzyme	Food	Type of spoilage
Ascorbic acid oxidase	Vegetables	Vitamin C destruction
Lipase	Cereals	Discoloration
	Milk	Rancidity
	Oils	Rancidity
Lipoxygenase	Vegetables	Vitamin A destruction and off-flavor
Pectic enzyme	Citrus juices	Pectic substances destruction
	Fruits	Softening
Peroxidase	Fruits	Browning reactions
Polyphenol oxidase	Fruits, vegetables	Off-flavor, browning, and vitamin loss
Protease	Eggs	Shelf-life reduction of fresh and dried eggs
	Crab, lobster	Excessive tenderization
	Flour	Gluten formation reduction
Thiaminase	Meats, fish	Thiamine destruction

Table 1.
Enzymes involved in the degradation of food quality.

3. Food storage

Food storage is an important part of food preservation, and many reactions during the storage cause quality degradation. Improper storage can adversely impact nutrient contents. For example, vitamin C and thiamine may be lost from foods during storage, especially at elevated temperatures [8]. Also, during storage, the food changes color, loses texture, and develops off-flavors. Therefore, the proper food storage system should be designed to avoid fresh foods with undesirable changes while retaining the maximum quality. One of the important parameters to consider in designing the food system is the

temperature [7]. Lower temperature storage is considered to reduce most of the reactions and results in minimum quality losses. In terms of storage environments, careful control of atmospheric gases such as oxygen, carbon dioxide, and ethylene of storage environments can extend fresh food storage [9]. For example, in North America, the apple industry utilizes controlled-atmosphere storage facilities to preserve the fruit's quality.

4. Food processing and preservation

Food processing by chemical or physical means converts the harvested food ingredients into food or other intermediate products [1]. It is the process of producing raw food ingredients into marketable products that consumers can easily prepare and use. In addition, it is easy to keep processed foods stored for a long time—examples include canned and frozen fruits and vegetables and fortified foods (micro or micro-nutrient-rich foods).

Food processing must be balanced with food preservation also. Food preservation is to stop or slow down the spoilage of food, and loss of quality, and improve the edibility of food for a longer time. Some technologies that increase food products' shelf life are heating, drying, canning, freezing, and others [10]. These technologies inactivate the microorganisms responsible for food spoilage and foodborne diseases or inhibit their growth. The major advantage of food processing is that it makes it more edible, palatable, and safe to consume and increases the shelf life after harvesting. New technologies were developed to meet the food requirements regarding quality, flavor, taste, and shelf life. Some commonly used food processing methods are chopping or slicing, mincing, liquefaction, fermentation, emulsification, cooking, mixing, and gasification, such as adding gas to bread or soft drinks [11]. In addition, some novel processing technologies were also developed to produce durable products available all year round regardless of their seasonality which, in turn, leads to reduced post-harvest loss.

Most food processes utilize six-unit operations: heat transfer, fluid flow, mass transfer, mixing, size adjustment, and separation [12]. The scope of food processing describes unit operations occurring after the harvest of raw materials until they are processed into food products, packaged, and shipped for retailing. The food preservation methods eliminate harmful pathogens present in the food and minimize or eliminate spoilage microorganisms and enzymes for the shelf-life extension. Food's physical, chemical, and thermal properties help identify the extent of process uniformity during physical, chemical, and thermal processes such as grinding, mixing, chemical modification, pasteurization, and sterilization. Therefore, food scientists and process engineers must adequately characterize the food's thermophysical and chemical properties.

4.1 Food preservation

The goal of food preservation is to prevent the growth of bacteria, fungi, or other microorganisms and retarding the oxidation of fats that cause rancidity, thus promoting longer shelf life and reducing hazards from eating the food [1]. The main goal of preservation is to increase the safety of food products. If the safety of the foods is compromised, it can result in contamination and cause widespread illness. Several food preservation methods are designed specifically to preserve food. Traditional methods are currently used to preserve food and extend its shelf life. Some traditional food preservation methods, such as heating, cooling, pickling, boiling, sugars, and others, are discussed below [3].

4.1.1 Freezing

Freezing is a process used to preserve a wide range of foods. The challenge of frozen foods is the change in texture and structure. For example, rapid freezing can adversely affect the texture of the foods [3].

4.1.2 Pickling

Pickling is a process where the foods are preserved in an edible and antimicrobial liquid, vinegar or vegetable oil, or anaerobic fermentation to increase the shelf life of foods [13]. There are two types of pickling: a) fermentation and b) chemical pickling. In the fermentation process, the bacteria in the liquid produces agents acting as preservatives, and in chemical pickling, the food is preserved in edible liquids that kill the microorganism and bacteria. The pickling method changes the food's texture, flavor, and taste. In Asia, pickling is widely used for many vegetables, including carrots, cauliflower, lemon, and raw mangoes [3]. In North America and other European countries, eggs, fish, and meat are also pickled [3]. During pickling, organic acids such as lactic acid and acetic acid are produced, which act as preservative agents. In addition to acids, brine is also used for food preservation. Both the acids and brine result in inhibiting the bacteria from growing.

4.1.3 Curing

The curing is used for vegetables, meat, and fish, where the moisture content is reduced using the osmosis dehydration process [14]. The osmotic dehydration process helps to reduce the moisture content of the foods such as fruits and vegetables, which helps to reduce microbial damage [14]. Curing also helps to improve the flavoring of the foods. Curing is done by adding salt, nitrates, sugars, and nitrites. Adding salt to the food products slows the oxidation process, which helps reduce the rancidity in the food products.

4.1.4 Fermentation

Food fermentation utilizes microorganisms' growth and metabolic activity to stabilize and transform food materials [15]. Fermentation is used for foods such as beer, wine, and cheese produced using microbes. During fermentation, the storage conditions, such as temperature, salt, oxygen level, and others, should be maintained to produce the microbes to preserve the food products.

4.1.5 Drying

This is one of the oldest technologies used for food preservation. This process exposes the food to sunlight to dry naturally. In addition, various types of commercial dryers are developed for drying foods—drying results in the evaporation of moisture content from food, further reducing the water activity and preventing the microorganisms from deteriorating the foods [1].

4.2 Modern methods for food preservation

4.2.1 Refrigeration

The cooling technique preserves the foods by reducing the growth of microorganisms and enzyme activity [16]. Some food products commonly stored using cooling methods

are meat, dairy, and fish, thus increasing the shelf-life of the products. Refrigeration is cooling the environment artificially to bring the temperature below ambient temperature. The refrigerator's temperature ranges from 4 to 10°C. Typically, bacterial growth is slowed at these temperatures, and most bacteria enter a dormant phase. For example, the enzymes which result in the degradation of food products at room temperature, under refrigeration slow the catalytic rate of enzymes and prevent the degradation. Refrigeration is used in many homes today to preserve fresh fruits, vegetables, meat, and milk products.

4.2.2 *Sugaring*

During the sugar preservation of the food products, the sugar makes the foods hypertonic, and microbes do not survive in hypertonic solutions. The hypertonic solutions suck the water from the microbes and dehydrate them. The foods such as fruits and vegetables are stored in sugar or honey; examples are hams and jellies. Also, many soft drinks and concentrates are prepared based on this principle.

4.3 Modern methods of food preservation

4.3.1 *Pasteurization*

Most microorganisms and spores could be destroyed by applying sufficient heat to food items. Therefore, high-temperature short time (HTST) and low-temperature short time (LTST) are commonly used to preserve foods [17].

4.3.2 *Freeze drying*

Freeze drying is also known as lyophilization. During this process, the moisture in the foods is removed under frozen and vacuum conditions at lower temperatures. The principle of this process is that the food's water is evaporated by sublimation at low pressure [3]. The low pressure and temperature during processing help the foods retain most of their quality attributes and shape. The process is used for heat-sensitive foods. The other technology widely used to preserve heat-sensitive foods is vacuum drying.

4.3.3 *Vacuum packing*

During vacuum packing, the foods are placed in a plastic bag, and a vacuum is created inside the bag, by sucking the air inside the bag [3]. Under no air storage conditions, the microbes do not grow and survive. This method is used for preserving nuts as it avoids oxidation reactions, such as rancidity, and preserves the flavor.

4.3.4 *Irradiation*

The foods are exposed to β -particles or γ -rays radiation during this process [3]. The radiation helps kill bacteria, molds, pests, and others. The World Health Organization and Food and Agricultural Organization approved this process [3]. This process is used for spices, condiments, and fresh fruits.

4.3.5 *Chemical preservatives*

Antimicrobial chemical agents are added for the long-term preservation of foods [3]. These chemical agents are added in small quantities, where large amounts

can be toxic. For example, acid and benzoates are used for food preservation in acidic foods, such as jams, salad dressings, juices, pickles, carbonated drinks, and soy sauce. Sorbic acids and sorbates are used for cheese, wine, baked foods, and others. In the case of meats, nitrates and nitrites are used to prevent the botulism toxin [3]. For fruits and vegetables, sulfur dioxide and sulfites are used, whereas propionic acid and propionates are used for baked foods.

4.3.6 Pascalization

In this process, the foods are exposed to very high pressure to the tune of high pressure, such as 70,000 lb. per square inch [3]. This process helps to retain the food's flavor, freshness, texture, and nutrients and destroys the microbes. After this treatment, the rate of food spoilage decreases significantly. This technique is mostly used for juices and meats.

4.3.7 Biopreservation

This process uses natural microbes or antimicrobials for preservation to improve the shelf life of foods [3]. In this process, beneficial bacterial or fermentation products are used to control and inactive the microorganism's growth [3]. Lactic and acetic acid bacteria are used as biopreservatives. These produce lactic acid, acetic acid, bacteriocins, and hydrogen peroxide, which act as antimicrobials and preserve the foods. D'Amico de Alcântara et al. [18] studied the antibacterial activity of *Lactobacillus rhamnosu* against *Pseudomonas fluorescens* and *Pseudomonas putida*, both isolated from refrigerated raw milk. These authors found that the antibacterial activity is due to organic acids produced.

4.3.8 Hurdle technology

In hurdle technology, more than one approach is used to inactive the microbes. The multiple preservation approaches act as hurdles for microorganisms and prevent their spoilage. Leistner [19] used hurdle technology, combining various hurdles that secure food from spoilage and preserve nutritional quality. Also, the hurdles do not induce smell or change the texture of preserved foods. Some of the hurdle approaches are high temperature, in combination with pressure, acidity, and adding biopreservatives. The selection of hurdles depends on the food's nature and potential pathogens.

4.3.9 Nonthermal plasma

In this process, the food surface is exposed to a flame of ionized gas molecules, such as nitrogen or helium to kill the microbes on the food's surface [3].

4.3.10 Modified atmosphere

In this process, the oxygen is reduced, and carbon dioxide is increased in the storage environment. For example, vegetable and fruit salad bags are stored in reduced oxygen and higher carbon dioxide environments [9, 20, 21]. These storage environments can result in the loss of some of the nutrients in the foods. This method is also used for the preservation of grains. The carbon dioxide used helps

to prevent the growth of insects, molds, and oxidation reactions and prevent grain damage. In the sealed room, the oxygen levels are reduced by infusing nitrogen gas [3]. On average, oxygen is 21% in the air, whereas, in such facilities, the oxygen level is reduced to 1 and 2%. Hermetic storage is an airtight storage widely used for storing grains. This method reduces the grain's respiration and prevents the growth of insects, fungi, and pests [22].

4.4 Benefits of food processing and preservation

The key reason is to maintain the quality and stability of a product. Fresh juice, for example, will easily phase-separate after extraction, and enzymes start to degrade valuable components, such as antioxidants. If these enzymes are inactivated by pasteurizing (heat-treating) the juice, spoilage can be slowed down [23]. This also applies to products that include a large amount of fat, as they easily become rancid when enzymes are still active and oxygen is present. Processing also makes some foodstuffs more digestible by softening tissue or breaking it down [1].

Furthermore, processing increases the variety of food products available to the consumer and makes them more convenient, meeting the demands of our on-the-go lifestyle. Lastly, food processing is important in ensuring that food is affordable. Furthermore, proper storage of foods, such as fruits, vegetables, and grains, can help reduce the spoilage and waste of foods and solve the food shortage in developing and underdeveloped countries.

Some of the major benefits and drawbacks of food processing and preservation are as follows:

- Reduces the bacteria growth, which can cause illness or diseases. For example, drying and pickling dehydrate the food product and alter the pH, preventing harmful microorganisms' growth.
- Improves the food product's shelf life.
- Processed food contains artificial ingredients.
- Over-processing of foods makes the food pleasant and leads to overconsumption.
- Most processed foods have high amounts of added sugar, which is very unhealthy.

5. Food packaging

Food packaging controls the storage environment and creates conditions extending food storage and shelf life. Some commonly used packaging materials are a) flexible paper, thin laminates, or plastic film; b) semi-rigid material such as aluminum foil, laminates, paperboard, and thermoformed plastic; and c) rigid material such as metal, glass, or thick plastic [24]. The most commonly used packaging material is plastic, which is cheap, lightweight, and easy to form in different shapes and sizes. In addition, plastic films with selective permeability properties to gases, carbon dioxide, and oxygen can be selected for storage [24, 25]. These films have led to the development of modified atmospheric packaging systems. By selecting the right barrier properties of the packaging materials, the shelf life of food products can be extended.

For example, intermediate moisture foods need to be protected from moisture during storage. Therefore, low moisture permeability packaging materials, such as polyvinyl chloride, polyvinylidene chloride, and polypropylene, can be used [26]. In the case of foods with high fatty acids, low gas permeability films can be used to reduce oxidation reactions. In the case of fresh fruits and vegetables, as they respire, packaging material such as polyethylene, which has high gas permeability, can be used. Currently, smart package systems offer properties that meet the special needs of certain foods [27]. For example, packages made with oxygen-absorbing materials remove oxygen from the inside, thus protecting oxygen-sensitive products from oxidation [28]. However, temperature-sensitive films exhibit an abrupt change in gas permeability when they are subjected to a temperature above or below a set constant. These films change from crystalline to amorphous at a given temperature, causing the gas permeability to change substantially. There are significant health and environmental concerns regarding using petroleum-based packaging materials such as plastics, polyethylene, and styrofoam, as they can release toxins into the foods when heated and can be dangerous to consumers, also they do not decompose for a long time, creating environmental issues. Packaging films made from biodegradable are gaining much importance in overcoming environmental issues. The packaging materials are made from polyhydroxyalkanoates (PHAs), biodegradable, and synthesized by various microorganisms, replacing petroleum-based plastics. These materials are environmentally friendly and, simultaneously, can be completely degraded by various microorganisms in a short time (less than a year).

6. Conclusions

Food processing and preservation are important to prevent food loss, improve storage stability, and retain most nutrients during storage. Improperly stored food can cause foodborne diseases if consumed and result in revenue loss. It is estimated that about 15% of the food produced is lost after post-harvest. Many traditional and modern preservation techniques have been developed for food storage. Traditional methods commonly used are pickling, curing, drying, and fermentation. The modern methods used for food preservation are pasteurization, freeze drying, vacuum packing, irradiation, chemical preservatives, pascalization, biopreservation, hurdle technology, nonthermal plasma, and a modified and controlled atmosphere. Both the traditional and modern methods can help improve the shelf stability of foods, such as meats, fruits, vegetables, and fish-based products. Although many existing techniques are used for food preservation, the selection of the preservation technique is based on technical and economic feasibility. In addition, novel and environmental friendly packaging methods are gaining much importance in retaining food quality during storage.

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