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28 Preservation of Plant and Animal Foods: An Overview

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Abstract: Generally, human food consists of resources of either plant or animal origin, which cannot be kept long after harvest or slaughter and starts deteriorating rapidly. Thus, it becomes imperative to find various ways of extending the shelf life of these materials/resources. The nature and characteristics of the material, like environment of the food and the interactions between the food and its environment, should be well understood. Traditional methods of food preservation include cold storage, fermentation, salting, drying, curing and smoking. However, the features of these traditional methods are largely centred on non-controllable processes that rely solely on 'chance effects'. Modern food preservation techniques include dehydration, refrigeration, freezing, industrial fermentation, freeze drying, irradiation, evaporation, concentration, thermal processing, use of chemical preservatives, high-pressure technology, plant-derived food preservation technology, modified-atmosphere packaging, use of bacteriolytic enzymes and a combination of two or more preservative methods (the hurdle concept), which lend themselves to controllable processes and allow for predictable final product quality attributes to be attainable. Traditional and modern food preservation techniques applicable to some of the common food raw materials are discussed in this chapter.

Keywords: food preservation; hurdle effect; modern methods; shelf life; traditional methods

28.1 INTRODUCTION: DEFINITION AND PRINCIPLES

Food preservation refers to methods used for keeping food from getting spoilt. Food spoilage is any adverse change that makes food unfit for human consumption and this process can be due to chemical and physical changes; for example, browning and bruising, growth of unwanted pathogenic microorganisms and infestation by insects or other pests. Thus food preservation is important in increasing/enhancing the shelf life of food and ensuring food safety. Extending the shelf life of foods is based on controlling enzymes or chemically active molecules in food, controlling microbial deteriorative processes and avoiding faulty post-harvest handling practices.

28.2 FOOD PRESERVATION METHODS

Ensuring that harvested commodities are alive with sustained chemical and respiration processes and the need to maintain moisture content and quality of produce during storage and to reduce diseases (Young *et al.*, 1998) are very important steps in post-harvest storage.

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Table 28.1 Examples of some selected storage methods for selected food commodities.

Food commodity	Storage method	References
Tomato	4–7°C Ethanol vapour and 5°C	Yanuriati *et al.* (1996); Decastro *et al.* (2006)
Apple	Controlled atmosphere + fungicide	Anonymous (1992); Errampali (2006)
Peanut, maize, spices	γ-Irradiation	Rizk and Botros (2006)
Shredded cabbage	Packaging films	Ibrahim *et al.* (2005)
Fresh sweetcorn (*Zea mays* L. var. *saccharatta*)	Forced-air cooling	Cortbaoui *et al.* (2006)
Cassava	Sealed polyethylene bags 3–30 ± 2°C	Akingbala *et al.* (2005)
Groundnut seeds	Polythylene lining + $CaCl_2$	Tripathy *et al.* (1996)
Pear (*Pyrus pyrifolia*)	Ethanol treatment	Jihuen and Seunghoo (1997)
Strawberries	Modified-atmosphere packaging (1°C/10 days)	Shamaila *et al.* (1992)

Extension of shelf life of foods can be carried out using refrigeration and freezing (www.fao.org), canning, drying and dehydration, film packaging, smoking, chemicals or food additives, forced-air cooling, modified/controlled atmospheric storage, irradiation and high-pressure food processing. Some examples of selected storage methods for various foods are listed in Table 28.1.

However, it must be noted that in order to extend shelf life and maintain quality of fresh fruits and vegetables, temperature management must be considered as an important factor (Kader and Marris, 1978; Van den Broeck *et al.*, 1998). Markarian *et al.* (2006) developed a mathematical model based on heat transfer, water vapour, temperature and other parameters for horticultural storage facilities and the results obtained correlated with those obtained for a potato storage facility.

Exposure of microorganisms to low temperatures reduces their rates of growth and reproduction. This principle is used in refrigeration and freezing. The microbes are not killed. In refrigerators held at 5°C, foods remain unspoilt. In a freezer at −5°C the crystals formed tear and shred microorganisms. This may kill many microbes but some are able to survive, like *Salmonella* spp. and streptococci. For these types of microorganisms rapid thawing and cooking are necessary. Deep freezing at −60°C forms smaller crystals and which reduces the biochemical activity of microbes.

Blanching of fruits and vegetables by scalding with hot water or steam prior to deep freezing inactivates plant enzymes that may produce a change in colour, etc. Brief scalding prior to freezing also reduces the number of microorganisms on the food surface by up to 99% and enhances the colour of green vegetables.

Refrigeration is the cooling of space and/or material below the general environmental temperature. It is applied to food material for the purpose of preservation. Refrigeration is used to extend the useful life of fresh and processed food that is required to be stored or transported from one place to another. Before the advent of modern refrigeration systems, perishable foods were kept in a cool environment such as cellars or buckets immersed in water. Sometimes ice from ice-making machines was used in cities to preserve foods. The advent of mechanical refrigeration systems significantly simplified the application of refrigeration to food preservation. The first patent for mechanical refrigeration was issued in 1834 in Great Britain to the American inventor Jacob Perkins. Although this requires access to a regular electricity supply it was one of the easiest methods for preserving food.

Freezing was used commercially for the first time in 1842, but large-scale food preservation by freezing began in the late 19th century with the advent of mechanical refrigeration. Freezing preserves food by preventing microorganisms from multiplying. The process does not kill all types of bacteria, however; those that survive reanimate in thawing food and often grow more rapidly than before freezing. Enzymes in the frozen state remain active, although they work at a reduced rate. Vegetables are blanched or heated in preparation for freezing to ensure enzyme inactivity and thus to avoid degradation of flavour. Blanching has also been proposed for fish to kill cold-adapted bacteria on the outer surface of the fish. Various methods are used to freeze meats depending on the type of meat and the cut. Pork is frozen soon after butchering but beef is hung in a cooler for several days to tenderize the meat before freezing.

Frozen foods have the advantage of resembling the fresh product more closely than the same food preserved by other techniques. Frozen foods also undergo some changes as freezing causes water in food to expand and tends to disrupt the cell structure by forming crystals. In quick freezing the ice crystals are smaller, producing less cell damage than if a product is frozen slowly. The quality of the product, however, may depend more on the rapidity with which the food is prepared and stored in the freezer than on the rate at which it is frozen. Some solid foods that are frozen slowly, such as fish, may, upon thawing, show a loss of liquid called drip, while liquid foods that are frozen slowly, such as egg yolk, may become coagulated.

Consumer-size packages of frozen food generally may weigh up to 0.9 kg. In one type of freezer used for tin packaged foods, the packages are transported mechanically on a conveyor belt through an air blast, which produces temperatures as low as –40°C. Another type of freezing technique, used in the freezing of concentrated orange juice, contains a secondary refrigerant, such as calcium chloride brine, as a spray-on bath for cans at temperatures of –29°C. In a widely used freezer called the plate freezer, the packages are put in contact with hollow metal plates containing a refrigerant and are subjected to pressure in order to increase the rate of freezing. This method of preservation is most widely used for a great variety of foods, including bakery goods, soups and precooked complete meals.

28.2.1 Precooling

Precooling, according to Kader (2002), may be carried out using forced air, water, liquid and vacuum. Vacuum cooling is recommended for hydro cooling and liquid icing cannot be used for highly moisture-sensitive containers (Vigneault and Goyette, 2002) or produce (Kader, 2002). The rate of cooling, further storage, shipping conditions and capital and labour costs are determining factors in choosing any precooling method for some plant products (Sargent *et al.*, 1998; Kader, 2002), Thus, Cortbaoui *et al.* (2006) used forced-air precooling to extend the storage life of fresh sweetcorn (*Zea mays* L. var. *saccharata*) for 21 days with resultant general good quality.

28.2.2 Canning

The process of canning is sometimes called sterilization because the heat treatment of the food eliminates all microorganisms that can spoil the food and those that are harmful to humans, including directly pathogenic bacteria and those that produce lethal toxins. Most commercial canning operations are based on the principle that destruction of bacteria increases 10-fold for each 10°C increase in temperature. Food exposed to high temperatures for only minutes or seconds retains more of its natural flavour. In the Flash 18 process, a continuous system, the food is flash-sterilized in a pressurized chamber to prevent the superheated food from boiling while it is placed in a container and further sterilizing is not required. Pasteurization combined with microfiltration can be used to extend the shelf life of milk. Milk packed in sterile containers and exposed briefly to temperatures higher than those required for pasteurization may be stored unopened for months without refrigeration.

28.2.3 Drying and dehydration

The terms drying and dehydration are applied to the removal of water from food. To the food technologist, drying refers to natural desiccation, such as by spreading fruit on racks in the sun, and dehydration designates drying by artificial means, such as with a blast of hot air. In freeze drying a high vacuum is maintained in a special cabinet containing frozen food until most of the moisture has sublimed. Removal of water offers excellent protection against the most common causes of food spoilage. Microorganisms cannot grow in a water-free environment, enzyme activity is absent and most chemical reactions are greatly retarded. This last characteristic makes dehydration preferable to canning if the product is to be stored at a high temperature. In order to achieve such protection, practically all the water must be removed. The food then must be packaged in a moisture-proof container to prevent it from absorbing water from the air. For this reason a hermetically sealed can is frequently used to store dry foods. Such a can offers the further advantage of being impervious to external destructive agents such as oxygen, light, insects and rodents.

Vegetables, fruits, meat, fish and some other foods, the average moisture content of which may be as high as 80%, may be dried to one-fifth of their original weight and about one-half of their original volume. The disadvantages of this method of preservation include the time and labour involved in rehydrating the food before eating. Furthermore, reconstituting the dried product may be difficult because it absorbs only about two-thirds of its original water content and this process tends to make the texture tough and chewy.

Drying was used in ancient times to preserve many foods. Large quantities of fruits such as figs have been sun-dried from ancient times to the present day. In the case of meat and fish, other preservation methods, such as smoking or salting, which yielded a palatable product, were generally preferred. Dehydration is confined largely to the production of a few dried foods, such as powdered milk, soup, potatoes, eggs, yeast and powdered coffee, which are particularly suited to the dehydration method.

Present-day dehydration techniques include the application of a stream of warm air to vegetables. Protein foods such as meat are of good quality only if freeze-dried. Liquid food is dehydrated usually by spraying it as droplets into a chamber of hot air, or occasionally by pouring it over a drum that is heated internally by steam.

Dehydration of food can be accompanied by chemical treatment. Raj *et al.* (2006) described a three-stage dehydration process following pretreatment with potassium metabisulphite used at 2.5 g/kg and obtained onion rings with good quality characteristics within 6 months of storage.

28.2.4 Packaging methods

Hussein *et al.* (2000), Carlin *et al.* (1990) and Barth *et al.* (1993) noted the usefulness of packaging and low-temperature storage of foods combined with high relative humidity in increasing shelf life by slowing the growth of spoilage organisms, and reducing physico-chemical and biochemical degradation processes as well as maintaining the nutritional and sensory qualities of minimally processed plant foods. According to Brown (1992) the use of modified atmospheres, gas flushing and vacuum packaging changes the atmosphere surrounding the food (e.g. fresh produce) in a such a way that the food's shelf life is extended. Vacuum packaging is normally used to remove air from a package's headspace and to a limited degree from the food itself to eliminate spoilage of the food by oxidation (Hui, 1992).

28.2.5 Antimicrobial-packaging technology

This method encompasses any packaging technique that can be used to control microbial growth in a given food product (Cha and Chinnam, 2004). Antimicrobial-packaging technology can be combined with lactic acid fermentation technology, making use of the hurdle concept to extend the shelf life of foods without refrigeration. Antimicrobial-packaging technology uses natural agents to control foodborne microorganisms and it will continue to be attractive technologically because of the increase in consumer demand for minimally processed and preservative-free products (Cha and Chinnan, 2001). Furthermore, No *et al.* (2007) also noted that the antimicrobial activity and film-forming properties of chitosan, a modified, natural biopolymer derived by deacetylation of chitin, a major component of the shells of crustaceans, make it potential food preservative or coating material of natural origin.

28.2.6 Smoking

Smoking is used for preserving fish, ham and sausage. The smoke is obtained by burning hickory or similar wood under a low draft. During the process of smoking, the preservative action is provided by bactericidal chemicals like formaldehyde and creosote in the smoke and by the dehydration that occurs in the smokehouse.

28.2.7 Chemical preservatives/food additives

Salt, sugar and benzoate are widely used in the food industry. Salt is a bactericidal agent that can be used to preserve fish or pork, either as dry salt or brine, while sugar is a major ingredient of jams and jellies. Sugar acts in much the same way as salt, inhibiting bacterial growth after the product has been heated. To ensure effective preservation, the total sugar content should at least make up to 65% of the weight of the final product. Vinegar (acetic acid) is used as a preservative in pickling relishes and other foods that have been heated.

Sodium benzoate is used in fruit products to protect against yeasts and moulds and its final concentration should not be more than 0.1%. Nwanekezi and Onyeali (2005) used sodium metabisulphite (100 ppm) and sodium benzoate (30 ppm) to extend the shelf life of bottled intermediate-moisture tomato paste; the product was stored at 33–38°C for 40 weeks without loss of quality.

Calcium propionate may be added to baked foods to inhibit moulds. Sulphur dioxide, permitted for use in some countries, can be added to dehydrated foods for colour retention. Preservation of fat- and lipid-containing foods from the development of objectionable colours and flavour and from the formation of decomposition products that can be toxic has been documented (Sims and Fioriti, 1977).

Adegoke *et al.* (1998) have also described the selection and classification of antioxidants for use in the food industry. Falola *et al.* (2008) used crude antioxidant extract from the spice *Aframomum danielli* (family Zingiberaceae) to extend the shelf life of *akara*, a cowpea paste with very poor keeping quality, for about 2 weeks. Some characteristics of *akara* have been described elsewhere (Hung and McWatters, 1990). Adegoke *et al.* (2000) used 200 ppm of antioxidant extract of *A. danielli* to stabilize soybean oil against oxidation for 28 days. Adegoke *et al.* (2004) also used antioxidant extract of *A. danielli* in combination with packaging to control lipid oxidation and fungal infestation of roasted peanut (*Arachis hypogea*) stored at 30°C for 35 days. The antioxidant extracts obtained from *A. danielli* have been reported to be more potent than butylated hydroxytoluene and butylated hydroxyanisole (Adegoke and Gopakrishna, 1998).

28.2.8 Shelf-life extension using additives of plant origin

Non-toxic and relatively cheap plant materials have been used to preserve foods (Pruthi, 1980; Charterjee, 1990; Adegoke and Sagua, 1993). Adegoke and Odesola (1996) used the powder and essential oil of lemon grass (*Cymbopogon citratus*) to preserve maize and cowpea for 10 days at 26±2°C. Furthermore, Adegoke *et al.* (2002) used the powder of *A. danielli* to protect maize (*Z. mays*) and soybeans (*Glycine max*) against mouldiness and insect infestation for 15 months with no loss of nutritive quality.

28.2.9 Food irradiation

Food irradiation can help to reduce high rates of food losses, especially with respect to cereals, root crops and dried foods (International Atomic Agency, 1990). Irradiation delays ripening of fruits and vegetables, inhibits sprouting in bulbs and tubers, disinfects grains, cereal products, fresh dried fruits and vegetables of insects, and destroys bacteria in fresh meats. Irradiation can extend the shelf life of several types of seafood stored at low temperatures (Licciardello and Ronsivaki 1982) and optimal radiation doses of 0.75–2.5 kGy can extend storage life by 2–6 weeks at 0–5°C (Angel *et al.*, 1986; Przybylski *et al.*, 1989). On a commercial basis, peppers are generally irradiated at doses of 5–10 kGy. Hayashi *et al.* (1994) used 5 kGy for the irradiation of black and white peppers stored at 3°C for 6 months.

28.2.10 High-pressure food processing

High-pressure treatment is a preservation method which does not involve high temperatures, and avoids undesirable alterations caused by thermal treatment of food such as vitamin loss, reduced bioavailability of essential amino acids, loss of flavour and modification of taste and colour (Butz *et al.*, 2003). Major advantages of using high pressure are inactivation of microorganisms (Hoover *et al.*, 1989) and quality retention and shelf-life extension (Shigeshisa *et al.*, 1991). High-pressure treatment is used for fruit jams, fruit juices, guacamole, sauces, oysters and packaged cured ham (Butz *et al.*, 2003).

28.2.11 Modified gas atmosphere

Prince (1989) defined modified-atmosphere packaging as 'the initial alteration of the gaseous environment in the immediate vicinity of the product, permitting the packaged product interactions to naturally vary their immediate gaseous environment.' Han *et al.*

(1985) and Kader *et al.* (1989) noted that development of a modified atmosphere within polymeric film can be used for extending the shelf life of fruits and vegetables. Farber (1991) reported that many modified atmospheres contain moderate to high concentrations of carbon dioxide. Proper sanitation and refrigeration can be used together with modified atmosphere to extend the shelf life of fresh red meats by reducing microbial load and retarding enzymic spoilage (Young *et al.*, 1988). Modified-atmosphere packaging which involves the use of gas mixtures including oxygen and carbon dioxide has been found to maintain the desired colour and inhibit undesirable microorganisms in red meat (Hotchkiss and Galloway, 1989).

A controlled atmosphere can be used for apple storage for more than 6 months to preserve fruit quality. However, to reduce the incidence of blue mould in apples that are stored for long periods of time under controlled-atmosphere storage in Canada, Australia and the USA, a pre-storage chemical control has been recommended (Koffman and Penrose, 1987; Eckert and Ogawa, 1988). Thus, after harvesting and before cold and controlled-atmosphere storage, the post-harvest use of thiabendazole (with or without application of antioxidant and diphenylamine, an anti-scalding agent) has been found to be useful for controlling storage rot and superficial scalding of apples (Anonymous, 1992). Selected storage methods that can be used for some food commodities are shown in Table 28.1.

28.3 CONCLUSION

As plant foods are good sources of essential nutrients for the human population, careful handling and storage of fruits and vegetables is of utmost importance because extended storage, high temperatures, low relative humidity, physical damage and chilling injury (Lee and Kader, 2000) can contribute to loss of essential nutrients. Synthetic chemicals are coming under very close scrutiny and consumers are interested in food that has undergone less thermal processing, so it is possible that more attention will now be focused on: (i) plant-derived food preservation technology encompassing use of natural plant products for antimicrobial packaging of plant and animal foods; and (ii) lactic acid fermentation technology. Whichever method is employed for storage of food commodities, the importance of careful handling procedures cannot be overemphasized.

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