Food Preservation

16

Introduction

This chapter is in the newly named *Aspects of Food Processing* section of the text. The chapters covering *food additives* and *food packaging* components of the food processing section appear in Chaps. 17 and 18, respectively.

The objective of food preservation is to *slow down* or *stop* (kill) bacterial spoilage activity that would otherwise exhibit loss of taste, textural quality, or nutritive value of food. Techniques of food preservation include heating, cold refrigeration, freezing, freeze drying, dehydration, concentrating, microwave heating, or other means as discussed in this chapter. For added clarification, and a succinct explanation, the following is utilized. See:

> Food *processing* and *preservation* are two techniques that are used to maintain the quality and freshness of foods. In terms of how they are performed, food processing and preservation are different; food preservation is just part of the entire procedure of processing foods. Food *processing* mostly involves both packaging and *preservation*, while food preservation is concerned with the control and elimination of the agents of food spoilage. Additionally, food processing is performed to turn food into something that is more palatable and convenient to eat. There are various methods of *food preservation, which include the addition of chemicals, dehydration, and heat processing. . . .*
>
> . . . Food processing and preservation are interrelated, as food is preserved to ensure quality before being packed for processing . . . (http://www.wisegeek.com/what-is-the-difference-between-food-processing-and-preservation.htm) (italics added)

Food Preservation

Techniques of *food preservation* may occur by heating (e.g., cooking, mild heat treatment methods such as blanching or pasteurization, severe heat treatment such as canning or bottling), cold refrigeration, freezing, freeze drying, dehydration, concentrating, microwave heating, or other means. These topics appear in this chapter.

Use of *additives* (Chap. 17) may be employed in preservation, namely, preservatives including those used in fermentation, chemical preservation, irradiation (FDA labels this an additive) salt (e.g., salting), sugar, and vinegar (e.g., pickling). As well, preservation may entail *packaging* (Chap. 18), including modifying or removing oxygen as a preservation technique.

In food processing, raw food ingredients are turned into foods that we might more readily eat. Food processing may be achieved in industry or in the home and may be simply referred to as cooking or baking.

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Storage conditions that foster preservation processes are subject to Food and Drug Administration (FDA) inspection and enforcement. Preservation from microbial, chemical, and physical contamination, as well as enzymatic activity, is necessary for preserving and extending the shelf life (time a product can be stored without significant change in quality) of food.

Heat Preservation

Heating or cooking foods as a means of preserving them or making them more palatable has been important for centuries. Heating is a vital form of food preservation, and as discussed in this chapter, there are many different methods of heating processes available today.

Foods are heat processed for four main reasons, enumerated below:

- To eliminate pathogens (organisms that cause disease)
- To eliminate or reduce spoilage organisms
- To extend the shelf life of the food
- To improve palatability of the food

Methods of Heat Transfer

Heat may be transferred to a food by conduction, convection, or radiation. Usually, the cooking process involves more than one of these heat transfer methods. Heat may also be generated directly in a food when it is microwaved and directly in the pan when an induction cooktop is used. The following listing offers a brief discussion of conduction (heat transferred through a solid), convection (heat transferred through the air), and radiation (direct heat—from the sun, broiling, grilling, electric range, and so forth). Microwaves and heating by induction are described later in the chapter.

Conduction is the term used for the transfer of heat from molecule to molecule and is the major method of transfer through a solid. Examples of heat transfer by conduction include a saucepan resting on a hot ring. The heat is transferred by direct contact with the heat source. Another example would be transfer of heat from the outside to the center of a large piece of meat. Conduction is a relatively slow method of heat transfer.

Convection occurs when currents are set up in heated liquid or gas. For example, as water is heated in a saucepan, the warmer sections become less dense and therefore rise, whereas the cooler regions flow down toward the bottom of the pan. This sets up a flow or current, which helps to spread the heat throughout the liquid. Heating by convection is therefore faster than heating by conduction.

Radiation is the fastest method of heat transfer. This occurs when heat is transferred directly from a radiant (red-hot) heat source, such as a broiler or a campfire, to the food to be heated. The energy is transferred in the form of electromagnetic waves, which may be transmitted through a gas such as air or through a vacuum. Any surfaces between the heat source and the food being heated reduce the amount of energy transmitted by radiation. The rays fan out as they travel, and so the farther a food is from the heat source, the fewer rays it receives and the longer it takes to get hot. (Heat transfer by radiation involves waves in the infrared region of the electromagnetic spectrum. Microwaves are also electromagnetic waves, yet of a different wavelength, and so they have a different effect on food, as discussed later on in the chapter.)

When food is cooked, more than one of these heat transfer methods is usually involved. For example, when roast chicken is cooked in the oven, heat is transferred to the outside of the chicken by radiation from the red-hot element and by convection due to the air currents in the oven; however, heat is transferred from the outside to the center by conduction.

Heat Treatment Methods: Mild or Severe

Heat treatment methods can be divided into two categories, depending on the amount of heat

Table 16.1 Overview of mild and severe heat treatments

Mild heat treatment	Severe heat treatment[a]
Aims	*Aims*
Kill pathogens	Kill *all* bacteria
Reduce bacterial count (food is *not* sterile)	Food will be commercially sterile
Inactivate enzymes	
Advantages	*Advantages*
Minimal damage to flavor, texture, and nutritional quality	Long shelf life
	No other preservation method is necessary
Disadvantages	*Disadvantages*
Short shelf life	Food is overcooked
Another preservation method must be used, such as refrigeration or freezing	Major changes in texture, flavor, and nutritional quality
Examples	*Examples*
Pasteurization, blanching	Canning

[a]See the section on canning

applied: the heat processing method may be *mild* or *severe*. The aims, advantages, and disadvantages of these two types of heat treatment are different. Depending on the objectives, a food processor may choose to use either a mild or a severe form of heat treatment to preserve a food product. Consumers rely on cooking to uphold conditions of food safety in the home. The two types of heat treatment will be discussed in detail; an overview of the main aims, advantages, and disadvantages of both is shown in Table 16.1.

Mild Heat Treatment

Examples of *mild* heat treatment include pasteurization and blanching.

Pasteurization is a *mild* heat treatment used for milk, liquid egg, fruit juices, and beer. The main purpose of pasteurization is to achieve the following as discussed in subsequent paragraphs below:

- Destroy pathogens
- Reduce bacterial count
- Inactivate enzymes
- Extend shelf life

Pathogens are microorganisms causing foodborne disease, either directly (foodborne infection), by releasing a substance that is toxic (foodborne intoxication), or via a toxin-mediated infection. All *pathogens must be destroyed* so that the food is safe to eat or drink; however, a pasteurized product is *not* sterile, the *bacterial count in a pasteurized product is simply reduced*. Any bacteria that are more heat resistant than those pathogens intended for destruction will not be destroyed, and they are able to grow and multiply in the food. They will cause spoilage of the food after a while, although that is usually obvious, as opposed to the unseen proliferation of pathogens causing contamination.

For a more detailed description of pasteurization of milk, see Chap. 11. Pasteurization of other products may differ in detail, yet the principles are the same. For example, egg white or whole egg is heated to 140–144 °F (60–62 °C) and held for 3.5–4.0 min to prevent growth of *Salmonella*. Fruit juices are also pasteurized, the main aim being to reduce the bacterial count and to inactivate enzymes, as fruit juices do not *normally* carry pathogenic microorganisms.

The mild heat treatment involved in pasteurization is usually sufficient to denature and *inactivate enzymes*. For example, milk contains the enzymes phosphatase and lipase, both of which are denatured during pasteurization (Chap. 11). To ensure that milk has been pasteurized properly, a colorimetric phosphatase test may be performed: if phosphatase is present, it turns a chemical reagent blue, indicating that the heat treatment has been insufficient. Absence of the blue color indicates that the phosphatase has been inactivated and the milk has been adequately pasteurized.

In order to *increase the shelf life* of a pasteurized product, it is necessary to refrigerate it to delay bacterial growth. For example, milk is pasteurized to ensure that it is safe to drink, although harmless bacteria are still present. If the milk is kept out on the kitchen counter on a warm day, the bacteria grow and produce lactic acid, and the milk turns sour within a day or two. However, milk can be stored in a refrigerator for at least a week, and sometimes longer, before it turns sour.

Blanching is another *mild* heat treatment, used mainly for vegetables and some fruits prior to freezing. The main aim of blanching is to *inactivate enzymes* that would cause deterioration of food during frozen storage. This is essential, because freezing does not completely stop enzyme action, and so foods that are stored in the frozen state for many months slowly develop off-flavors and off-colors.

Blanching usually involves dipping the vegetable in boiling or near-boiling water for 1–3 min. Blanching treatments have to be established on an experimental basis, depending on size and shape and enzyme level of the different vegetables. For example, peas, which are very small, require only 1–1.5 min in water at 212 °F (100 °C), whereas cauliflower and broccoli that are broken into small flowerets require 2–3 min. Corn on the cob is blanched for 7–11 min depending on size to destroy the enzymes within the cob itself.

Some, yet not all, destruction of bacteria is achieved during blanching, and the extent depends on the length or the heat treatment. As with pasteurization, blanching does *not* produce a sterile product. Foods that have been blanched require a further preservation treatment such as freezing in order to significantly increase their shelf life.

Severe Heat Treatment

Canning

Canning is a well-known method employed in food preservation. It involves hermetically sealing food in a container and then inhibiting pathogenic and spoilage organisms with the application of heat. Nicolas Appert (1752–1841) is credited with the thermal process of canning (vacuum bottling technique), which was discovered in 1809 as a result of a need to feed Napoleon's troops. Soon afterward, in 1810, Peter Durand received a patent for the tin-plated can. Decades later, Louis Pasteur understood the principle of microbial destruction and was able to provide the explanation for canning as a means of preservation. Samuel Prescott and William Underwood of the United States established further scientific applications for canning, including time and temperature interactions, in the late nineteenth century.

Canning (Table 16.1) is an example of a food processing method that involves *severe* heat treatment. Food is placed inside a cylinder, or body of a can, the lid is sealed in place, and the can is then heated in a large commercial pressure cooker known as a retort. Heating times and temperatures vary, although the heat treatment must be sufficient to sterilize the food (Potter and Hotchkiss 1995). Temperatures in the range 241–250 °F (116–121 °C) are commonly used for canning. Calcium may be added to canned foods as it increases tissue firmness.

> The main purpose of canning is to achieve the following:
> - Commercial sterility
> - Extended shelf life (more than 6 months)

Commercial sterility is defined as "that degree of sterilization at which all pathogenic and toxin-forming organisms have been destroyed, as well as all other types of organisms which, if present, could grow in the product and produce spoilage under normal handling and storage conditions."

Table 16.2 Logarithmic death rate

Time (min)	No. of survivors
1	1,000,000
2	100,000
3	10,000
4	1,000
5	100
6	10
7	1
8	0.1
9	0.01

Commercially sterilized foods may contain a small number of heat-resistant bacterial spores that are unable to grow under normal conditions. However, if they were isolated from the food and given special environmental conditions, they could be shown to be alive (Watanabe et al. 1988).

A good number of commercially sterile foods have a shelf life of 2 years or more. Any product deterioration that occurs over time is due to texture or flavor changes, not due to microbial growth.

In the case of canning fruits and vegetables, the canneries may be located immediately near the field. The raw food is washed and prepared, blanched, placed into containers, perhaps under a vacuum (to mechanically exhaust the air), sealed, sterilized to destroy remaining bacteria, molds, and yeasts (240 °F (116 °C)), then cooled and labeled. Next, the can is sent to the warehouse for storage prior to distribution.

Bottling

The bottling process helps in preserving foods. Using a sterile bottle and subsequent boiling deters or destroys any bacteria. Once opened the bottle contents may begin the spoilage process. If the bottled contents are *high-acid* foods, they are subject to reduced boiling and use of less preservatives.

The Effect of Heat on Microorganisms

Heat denatures proteins, destroys enzyme activity, and, therefore, kills microorganisms. Bacteria are destroyed at a rate proportional to the number present in the food. This is known as the *logarithmic death rate*, which means that at a constant temperature, the same percentage of a bacterial population will be destroyed in a given time interval, irrespective of the size of the surviving population (Table 16.2).

In other words, if 90 % of the bacterial population is destroyed in the first minute of heating, then 90 % of the remaining population will be destroyed in the second minute of heating, and so on. For example, if a food contains one million (10^6) organisms and 90 % are destroyed in the first minute, then 100,000 (10^5) organisms will survive. At the end of the second minute, 90 % of the surviving population will be destroyed, leaving a population of 10,000 (10^4) microorganisms. This is illustrated in more detail in Table 16.2.

If the logarithm number of survivors is plotted against the time at a constant temperature, a graph is obtained like the one shown in Fig. 16.1. This is known as a ***thermal death rate curve*** (Fig. 16.1). Such a graph provides data on the rate of destruction of a specific organism in a specific medium or food at a *specific* temperature.

An important parameter that can be obtained from the thermal death rate curve is the ***D value*** or ***decimal reduction time***. The *D* value is defined as the time in minutes at a specified temperature required to destroy 90 % of the organisms in a given population. It can also be described as the time required to reduce the population by a factor of 10, or by one log cycle.

The *D* value varies for different microbial species. Some microorganisms are more heat resistant than others; therefore, more heat is required to destroy them. The *D* value for such organisms will be higher than the *D* value for heat-sensitive bacteria. A higher *D* value indicates greater heat resistance, because it takes longer to destroy 90 % of the population.

Destruction of microorganisms is temperature dependent. Bacteria are destroyed more rapidly at higher temperatures; therefore, the *D* value for a particular organism decreases with increasing temperature. For a specific microorganism in a specific food, a set of *D* values can be obtained at different temperatures. These can be used to plot a ***thermal death time curve*** (Fig. 16.2) with the

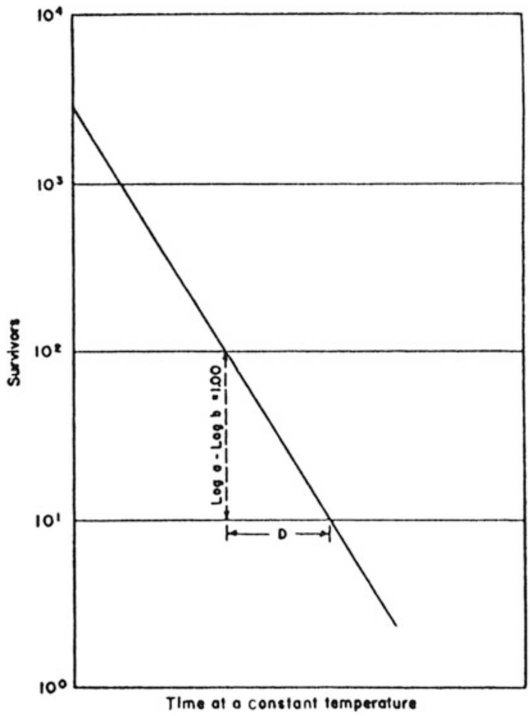

Fig. 16.1 A typical thermal death **rate** curve (*Source*: Stumbo, Thermobacteriology in Food Processing, 2nd ed. Academic Press, NY, 1973)

logarithm of the time plotted on the *Y* axis and the temperature on the *X* axis.

A thermal death time curve provides data on the destruction of a specific organism at different temperatures. The heating time on the graph may be the *D* value or it may be the time to achieve 12*D* values, as will be explained later. The important thing to remember about the thermal death time curve is that every point on the graph represents destruction of the same number of bacteria. In other words, every time–temperature combination on the graph is equivalent in terms of killing bacteria. Such graphs are important to the food processor in determining the best time–temperature combination to be used in canning a particular product and ensuring that commercial sterility is achieved.

Additional parameters shown on the thermal death time curve are beyond the scope of this book, and so will not be explained in detail here. (The *z* value indicates the resistance of a bacterial population to changing temperature and the *F* value is a measure of the capacity of a heat treatment to sterilize.)

Selecting Heat Treatments

All canned food must be commercially sterile and must therefore receive a heat treatment that is sufficient to kill essentially all bacterial vegetative cells and spores. However, such severe heat treatment adversely affects food qualities such as texture, flavor, and nutritional quality. The food processor aims to ensure commercial sterility and to achieve this using the mildest heat treatment possible, so that the food does not taste too "overcooked."

In other words, the optimal heat treatment will do the following:

- Achieve bacterial destruction (commercial sterility)
- Minimize adverse severe heat effects
- Be the mildest heat treatment necessary

In order to select a safe heat preservation treatment, it is important to know the time–temperature

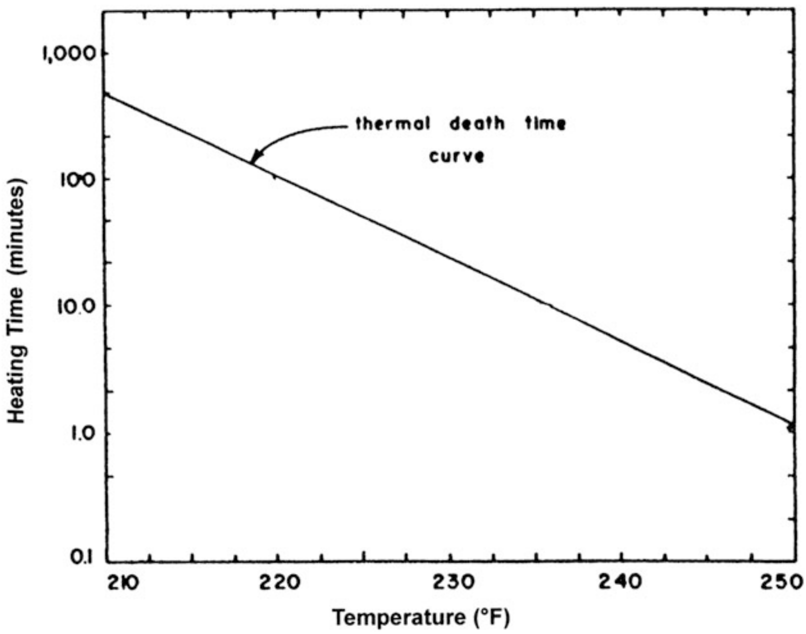

Fig. 16.2 A typical thermal death **time** curve (*Source*: Adapted from Desrosier and Desrosier, Technology of Food Preservation, 4th ed. AVI Publishing Co. Westport, CT, 1977)

combination required to inactivate the most heat-resistant pathogens and spoilage organisms in a particular food. This depends on several factors:

1. *The heat penetration characteristics of the food*. The food in the center of the can must receive sufficient heat treatment to achieve commercial sterility. This may mean that the food toward the outside of the can is overcooked. How fast the heat penetrates to the center of the can depends on the size of the can and also on the consistency of the food. Heat will reach the center of liquid foods, such as soup, much more quickly than solid foods such as meat.
2. *The pH of the food*. Bacteria are more heat resistant at neutral pH than they are in acid. Therefore, high-acid foods, such as tomatoes or fruits, need a less severe heat treatment to achieve sterility.
3. *The composition of the food*. Proteins, fats, and sugar in high concentrations all have a protective effect on bacteria, because they hinder the penetration of wet heat; thus, a more severe heat treatment is needed to sterilize foods that are high in protein, fat, or sugar.
4. The pathogenic and spoilage organisms likely to be present.

In order to ensure commercial sterility, it is important to have thermal death time curve data available for the most heat-resistant microorganisms that may be present in the food. Such data must be obtained for the food to be processed, as the composition of the food affects the heat sensitivity of the bacteria. Thermal death time curves obtained in one food may not apply to the same bacteria in a different medium. Without obtaining thermal death time curves for the specific food, it is impossible to ensure commercial sterility.

As has already been mentioned, every point on the thermal death time curve is equivalent in terms of destruction of bacteria. An increase in temperature greatly reduces the time required to achieve commercial sterility. However, the color, flavor, texture, and nutritional value of foods are not as sensitive to temperature increase. Generally speaking, a 50 °F (10 °C) rise in temperature *doubles* the rate of chemical reactions and causes a *tenfold* increase in the thermal death rate. Therefore, a high-temperature short-time combination is preferred, in order to minimize adverse chemical changes in the food such as loss of flavor, texture, and nutritional quality.

The food processor wants to use the time–temperature combination that causes the least damage to food quality.

Refrigeration Preservation

Refrigeration is another means of food preservation discussed in this chapter. Our ancestors were familiar with placing food in cold cellars, holes in the ground, or natural caves, as these storage sites would assure uniform temperatures in storage and preserve food.

Ice became widespread as a means of cold preservation in the middle 1800s—food was stored in a closed, wooden "ice box" that contained a block of ice in a chamber above the food to keep it cold. *Mechanical* refrigeration was introduced in the later 1800s and has undergone enormous developments since then. Even so, there are persons who may still refer to the refrigerator as the "ice box"!

Refrigerator and freezer temperatures both fail to sterilize food, yet the latter temperatures are more effective in retarding bacterial growth. Refrigerated food is generally held at temperatures below 45 °F (7.2 °C) (or 41 °F (5 °C)) and is subject to *state* or *local* FDA or USDA handling, storage, and transport requirements.

The extended shelf life of refrigerated foods poses microbiological and safety quality issues both at home and at the plant. A food may be better preserved in storage if it is stored under controlled atmospheric (CA) conditions. CA extends shelf life by reducing oxygen and increasing carbon dioxide in the atmosphere surrounding fruits (Chap. 7). Controlling gases in the atmosphere is also useful in providing longer storage of meats (Chap. 9) and eggs (Chap. 10). Meat preservation, for example, involves controlling microbial growth, retarding enzymes, and preventing the development of rancidity through the oxidation of fatty acids.

Packaging materials may be used in conjunction with refrigeration of food in order to preserve foods. Simply covering a food inhibits unwanted dehydration and contamination, yet as a later chapter will address, the correct choice of film material used may also assist in prolonging shelf life.

Problems Associated with Refrigeration

Spoilage, or damage to the edible quality of food, is possible without maintenance of the proper temperatures and humidity, use of FIFO, and regular cleaning.

Cross-contamination, or the transfer of harmful substances from one product to another, is possible without adequate covering or placement of foods. Pathogens from an improperly placed raw product may contaminate other food.

Temperatures. If temperatures are *too cold*, "chill injury" to fresh vegetables or fruits or sugar development in potatoes may result. Low-temperature storage increases the starch content of sweet corn (Chap. 7). *High* refrigerator temperatures or large containers of food that cannot cool quickly can lead to foodborne illness. Potentially hazardous foods must be kept at 41 °F (5 °C) or less and, if refrigerated after preparation, must be cooled to 41 °F (5 °C) or less in 4 h or less. The Centers for Disease Control and Prevention (CDC) report that improper cooling (including improper cooling in the refrigerator) is, by far, the number one cause of bacterial growth leading to foodborne illness (see local jurisdiction).

Odor. Odors may be transferred from some foods, such as onions, to butter, chocolates, and milk. If possible, strong odor foods should be stored separately from other foods. Packaging may be utilized to minimize odor problems.

Table 16.3 Why use liquid nitrogen freezing? (*Source*: Air Products)

Why use liquid nitrogen freezing instead of ammonia or Freon?
• Freezing in seconds instead of hours—LIN is one of the coldest refrigerants on earth
• Enhanced product quality with faster freezing, resulting in smaller ice crystals
• Increased production yields—less dehydration and moisture loss
• Lower capital costs
• Colder LIN temperatures equal smaller equipment footprint

Fig. 16.3 Example of cryogenic freezing of foods—hamburger patties (*Source*: Air Products)

Freezing Preservation

Frozen food is held at colder temperatures than refrigerated food—obviously. As opposed to refrigerator *short-term storage*, freezing is a *long-term storage* form that entails several months or a year. In freezing, water is rendered unavailable for bacteria; thus, bacteria are dormant, and consequently, there is no multiplication of pathogens. Foods freeze as their water component turns to ice, or *crystallizes*.

Freezing Methods

Rapid freezing by commercial freezing methods includes the following procedures including air blast tunnel freezing, plate freezing, and cryogenic freezing as described below:

Air blast procedures utilize convection and cold air. With this method of freezing, foods are placed either on racks that are subsequently wheeled into an insulated tunnel, or on a conveyor belt, where very cold air is blown over the food at a quick speed. When *all* parts of the food reach a temperature of 0 °F (−17.8 °C), the packages are put into freezer storage. The products may be packaged prior to or following freezing.

In *plate freezing*, the packaged food is placed between metal plates, which make full contact with the product and conduct cold, so that *all* parts of the food are brought to 0 °F (−17.8 °C). Automatic, continuous operating plate freezers can freeze the food and immediately deposit it to areas for casing and storage.

Cryogenic freezing may involve either *immersion* or *spraying* the food product with liquid nitrogen (LIN). LIN has a boiling point of −320 °F (−196 °C) and therefore freezes food more rapidly than other mechanical techniques (Table 16.3). Food such as meats, poultry, seafood, fruits, and vegetables, prepared or processed foods, may be preserved by cryogenic freezing (Fig. 16.3).

Cryogenic techniques for freezing include use of tunnel freezers that use LIN sprayed onto food. The LIN vaporizes to nitrogen gas at −320 °F (−196 °C), at the end of the tunnel, and is then recirculated to the tunnel entrance. LIN (Fig. 16.4) is approved by the FDA's Food Safety and Inspection Service (FSIS), for contact and freezing both meat and meat products and poultry and poultry products.

Cooking in a private residential situation, the consumer does not usually have access to these aforementioned options and it is recommended that no more than 2–3 lb of food per cubic foot of food be placed in the freezer at one time.

In order that physical damage to frozen food is minimized, the speed of freezing comes into play. For example, with a *slow* freeze, *extracellular* crystallization occurs prior to *intracellular* crystallization. This slow freezing speed is destructive, and as a result, water is drawn from

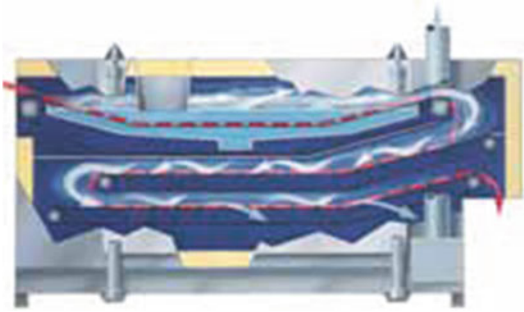

Fig. 16.4 Example of the cryogenic immersion freezing process. LIN immersion technology in a multitiered freezing system (*Source*: Air Products)

the inside of the cell as the external solute concentration increases. Consequently cell walls tear and shrink. At a cellular level, there is physical damage to the food as the water expands and the extracellular ice crystallization separates cells.

In opposition to a slow and damaging freeze, food tissues survive a *rapid* freeze better than a slow freeze. In a rapid freeze situation, water does not have time to migrate to seed crystals or form large, destructive ice crystals.

Problems Associated with Freezing

The preponderance of the problems associated with freezing is due to *physical damage*. This damage may be due to formation of ice crystals. Also, changes in texture and flavor may be caused by the *increased solute concentration* that occurs progressively as liquid water is removed in the form of ice.

These effects of ice crystals, texture and flavor, are minimized by fast freezing methods. Fast freezing minimizes formation of large crystals that would cause the most damage to cell structure and colloidal systems. Ice crystals can actually rupture cell walls, break emulsions, and cause syneresis in gels.

Increases in solute concentration can cause changes in pH, denaturation of proteins, and increased enzyme activity, all of which may lead to deterioration of food quality. Fast freezing shortens the time period during which the concentration effects are important, thereby decreasing their effect on food quality.

Recrystallization may be a problem in maintaining a high-quality product. With refreezing, ice crystals enlarge because they are subject to fluctuating temperatures. Evidence of refreezing is frequently observed with large crystalline formation on the inside of the package.

Freezer burn is the dehydration that may accompany the freezing process. The surface of food may show white patches and becomes tough. This occurs due to sublimation of ice. Solid ice will become a moisture vapor, bypassing the liquid phase, and the vapor pressure differential between the food material and the atmosphere will lead to sublimation and desiccation. The use of moisture-proof freezer wraps is suggested for storage.

Oxidation may lead to the development of off-flavor fats, as the double bonds of unsaturated fats are oxidized. Fruits and vegetables may brown during freezer storage due to enzymatic oxidative browning if enzymes are not denatured before freezing. Vitamin C (ascorbic acid) may be oxidized.

Colloidal substance change in freezing may occur due to the following:

- Starch syneresis—the freezing and thawing cycle may produce "weeping" because in thawing, less water is reabsorbed than what was originally present (Chap. 4).
- Cellulose becomes tougher.
- Emulsions break down and are subject to dehydration and precipitation.

Chemical Changes to Frozen Foods

Chemical changes to foods may occur as they are frozen. Off-odors may develop as acetaldehyde is changed to ethanol. As mentioned earlier, in oxidation, enzymatic oxidative browning is observable as phenols react with available oxygen, and ascorbic acid may become oxidized. It is recommended that blanching occur prior to freezing, as it may prevent oxidation. Pigments such as chlorophyll undergo degradation.

An illustration is apparent, for example, when eggs are frozen. Eggs show an increased concentration of soluble salts in unfrozen portions if freezing is slow. Specifically, the egg *yolks* show granule disruption due to an aggregation of low-density lipoproteins, forming a gummy product.

Moisture Control in Freezing

Drying occurs when a food gives up water to the atmosphere. Such dehydration also draws water from bacterial cells too, which is needed for subsequent growth outside of the freezer.

CULINARY ALERT! In 1930 Clarence Birdseye was awarded a US patent for a "Method of Preparing Food Products," a system that packed fish, meat, and vegetables in waxed cartons that were then flash-frozen. Now the Birdseye name still appears on high-quality frozen food.

> An astute naturalist employed by the United States government was the first to take particular notice of how the Eskimos prepared their frozen fish. On duty in the Arctic, Clarence Birdseye watched in fascination as the Arctic ice and the bitter Arctic wind froze the fresh fish almost instantly. More importantly, Birdseye found that when these frozen fish were later thawed, cooked, and eaten, their taste was remarkably similar to the original fresh food. Recognizing that this "flash" or practically instantaneous freezing had commercial potential, Birdseye left his government job and formed Birdseye Seafoods, Inc. in 1924. In 1930 he was awarded a United States patent for a "Method of Preparing Food Products" (#1,773,079), a system that packed fish, meat and vegetables in waxed cartons that were then flash-frozen.
>
> Regarding frozen food research, "For practical purposes, the question was to determine what variance in the ideal temperature a product could withstand without affecting its quality. That is, "what is the tolerance of a frozen food to adverse conditions, measured in terms of time and temperature combinations?" In typical scientific fashion, this title was shortened simply to the T-TT studies (Frozen Foods Research: Time–Temperature Tolerance Studies—American Chemical Society)

Dehydration Preservation

Dehydration is a means of preservation that subjects food to some degree of water removal. The primary intent is to reduce moisture content and preclude the possibility of microbial growth such as bacteria, mold, and yeast. A decrease in relative humidity (RH) leads to a decrease in microorganism growth.

Even as traditional methods of drying are utilized around the world, new drying techniques are being developed.

> Methods used for drying foods include the following:
>
> - Natural or sun drying—dries by direct sunlight or dry, hot air.
> - Mechanical drying—dries with heated air blown in a tunnel, cabinet, or tray that contains the food (fluidized-bed drying, where hot air passes through the product and picks up moisture, is a special type of hot air drying).
> - Drum drying—dries the product on two heated stainless steel drums before it is scraped off. Milk, juices, and purees may be dried in this manner.
> - *Freeze drying—freezes* and subsequently *vacuums* to evaporate moisture in the process of sublimation (ice is converted to a vapor without passing through the liquid phase); examples include instant coffee, meats, and vegetables.
> - Puff drying—either by *heat* and subsequent *vacuum* (to increase the pressure difference between the internal and external environments) or a combination of vacuuming and steaming. The product may also puff as the temperature of the water in the food is raised above 212 °F (100 °C) and then external pressure is quickly released. Examples are some ready-to-eat puffed cereal products.
> - Vacuuming a food environment removes any necessary oxygen for aerobic bacteria and may serve to reduce loss of flavor due to oxidation.
> - Smoking—preserves by dehydrating, thus offering microbial control (Chap. 9) and also treats meat to impart flavor by exposure to aromatic smoke.

- Spray drying—dries the product as it is sprayed into a chamber concurrently with hot air. For example, eggs, instant coffee, and milk may be spray-dried.

The result of any dehydration is increased shelf life and a reduction in distribution costs due to less weight.

Deterioration may occur even in dried products. Detrimental color, flavor, or textural changes may result from enzymatic changes, and these may be controlled by deactivating enzymes, by blanching, or adding sulfur compounds prior to dehydrating. Nonenzymatic browning may occur in dried foods either due to caramelization or the Maillard browning. The Maillard reaction products may lead to significant unwelcome browning, development of bitter flavors, less solubility of proteins, as well as diminished nutritive value. Dry milks or eggs and breakfast cereals participate in this reaction. Overall, oxidative spoilage, or chemical changes by oxidation of fats, is the primary cause of deterioration.

Factors needing control in dehydration include atmospheric conditions such as temperature, humidity, pressure, and portion size. The length of storage time is also a factor in the quality of the end product.

Concentration to Preserve Food

Foods are ***concentrated***, primarily in order to reduce weight and bulk. This makes transportation, shipping, and handling easier and less expensive, and so, it is economically advantageous. Many foods are concentrated, including fruit and vegetable juices and purees, milk products, soups, sugar syrups, jams, and jellies, to name a few.

Concentration is not usually considered to be a method of preservation of a food, since the water activity is not reduced sufficiently to prevent bacterial growth (see Chap. 2). The exception to this is jams and jellies, which contain high levels of sugar. Additional preservation methods, such as pasteurization, refrigeration, or canning, are therefore used to prevent spoilage of concentrated foods.

Methods of Concentration

Some of the more common methods of concentration are as follows:

- Open kettles—used to concentrate maple syrup, where the high heat produces the desired color and flavor. They are also used for jellies, jams, and some types of soups. The disadvantage of open kettles is the risk of product burn-on at the kettle wall due to high heat and long processing times.
- Flash evaporators—use heated steam (150 °C), which is injected into the food and later removed, along with water vapor from the food. This reduces heating time, but temperatures are still high, and so foods may lose volatile flavor constituents.
- Thin-film evaporators—enable the food to be continuously spread in a thin layer on the cylinder wall, which is heated by steam. As the food is concentrated (by removal of water vapor), it is wiped from the wall and collected. Heat damage is minimal due to the short time required to concentrate the food.
- Vacuum evaporators—used to concentrate heat-sensitive foods, which would be damaged by high heat. Operation under vacuum allows concentration to be achieved at much lower temperatures.
- Ultrafiltration and reverse osmosis—expensive processes that may be operated at low temperatures and use selectively permeable membranes to concentrate liquids. Different membranes are required for different liquid foods. These processes are used to concentrate dilute protein dispersions

such as whey protein, which cannot be concentrated by traditional methods without being extensively denatured. Ultrafiltration involves pumping the dispersion under pressure against a membrane that retains the protein but allows smaller molecules such as salts and sugars to pass through. Reverse osmosis is similar, but higher pressures are used, and the membrane pores are smaller, and so they are able to hold back various salts and sugars, as well as larger protein molecules.

Changes During Concentration

The product changes that occur during concentration arise primarily due to exposure of food to high heat. A "cooked" flavor may develop, and discoloration may occur. In addition, the product may thicken or gel over time, due to denaturation of proteins. This is a potential problem in evaporated milk. Nutritional quality may also be lost. The extent of the changes depends on the severity of the heat treatment.

Concentration methods that employ low heat or short processing times cause the least damage to food. However, they are also the most costly and may not always be the practical choice for the food processor, who must balance cost against quality.

Added Preservatives

Preservatives may be used along with preservation techniques such as heating, refrigerating, freezing, canning, and so forth. Specific preservatives may be applied to a food to extend shelf life:

- **Acid**—denatures bacterial proteins, preserving food, although not always sufficient to ensure sterility. Acid may be naturally present in foods such as citrus fruits and tomatoes. The combination of acid and heat provides more effective preservation.
- **Sugar and salt**—heavy syrups or brines compete with bacteria for water. By osmosis, the high percentage of water moves out of bacterial cells to equal the lower level of water in the surrounding medium. Other microorganisms, such as the fungi, yeast, and mold, are capable of growing in a high sugar or salt environment. Early US settlers preserved meats using salt and sugar.
  Sugar *syrups* may be used in preserving seasonal fruits, and *crystallized* sugar is found in cooked, candied fruit peels.
- **Smoke**—may contain a preservation chemical such as formaldehyde. Smoke retards bacterial growth due to surface dehydration. Smoking may also be used simply to impart flavor.
- **Vinegar**—used to create an acidic environment. Pickling controls the growth of microorganisms.
- **Chemicals**—subject to FDA approval. The burden of proof for usefulness and harmlessness is on industry. The chemical properties of the foods itself, such as pH and moisture content, affect the growth of microorganisms.

Fermentation—with the addition of nonpathogenic bacteria to a food, acid is produced, the pH is reduced, and the growth of pathogenic bacteria is controlled.

Radiation to Preserve Food

Foods may be heated by radiation, including the use of microwave heat treatment, or the lesser heat of irradiation. As has already been mentioned, these are both different from the radiation that occurs from a red-hot heat source such as a broiler or a fire, because of the frequency of the electromagnetic waves, which determines the effects of the radiation on food

Microwave Heating

Microwave heating is a nonionizing, rapid method of cooking. It may be used for both processing and preservation. It is reported that microwave heating inactivates vitamin B_{12}, which is found in animal products and fortified vegetarian products. The nutrient plays an important role in maintaining the nerve tissue (Watanabe et al. 1988). In combination with newer food packaging technologies, microwaveable foods are plentiful in the marketplace.

Microwaves are high-frequency (2.5 GHz) electromagnetic waves that cause heat to be generated in the food itself, due to the friction generated as polar molecules such as water try to align with the constantly changing electromagnetic field they produce. Microwave heating is fast and efficient, and since heat is generated within the food, the oven does not get hot.

Nevertheless, microwave heating is uneven, and hot and cold spots are generated within the food. The presence of localized cold spots could present a health hazard when cooking poultry or raw meat; it is important to check the internal temperature in several places if poultry is cooked in the microwave, to ensure that the correct temperature has been reached throughout. Microwaves penetrate 1–2 in. into the food; beyond that, heat is transferred by conduction, if the food is solid. Small portions are therefore best suited for microwave cooking. Large portions tend to overcook on the surface before the heat reaches the center.

Microwave-safe containers must be used in a microwave oven. These include containers that transmit microwaves, such as glass, ceramic, and some plastics. Containers that absorb microwaves, and therefore get hot, should not be used. Metal containers should also not be used, since they reflect the microwaves, which can cause arcing, and possibly a fire.

Foods do not generally "brown" when microwaved, since the surface does not get as hot as in a conventional oven. However, special packaging has been developed for some food products that allows for browning; for example, Hot Pockets and some chicken pot pies have metalized coatings that cause reflection of the microwaves back onto the surface, allowing browning of the crust. Ingredients such as commercially available liquid browning sauces and powders may be added for the purpose of fostering browning.

General recommendations to be followed when heating by microwave include the following:

- Turn the container while cooking to avoid "hot spots" of concentrated energy in one spot.
- Include a "rest period" or "standing time" beyond the designated cooking time, in order to continue cooking the food.
- Beware of hot containers from conduction of heat from food to the container.
- Select a low power setting for defrosting. Microwave energy is then sent intermittently into the frozen food.

Several definitions relating to the microwave method of heating include the following:

Hot spots—the nonuniform heating of high-water foods

Molecular friction—the heat generation method of microwave heating

Skin—the surface dehydration and hardening as more microwave energy is absorbed at the surface of the food

Shielding—protection of portions of food such as cylindrical ends of food, which readily overcook

Thermal runaway—differential heating of food without thermal equilibrium

Irradiation

Irradiation is the administration of measured doses of energy that are product-specific. A positive biological effect is that it has a **bactericidal** effect, thus reduces the microbial load of a food, kills insects, and controls ripening. It also inhibits the sprouting of some vegetables.

Irradiation is a cold process of food preservation that does not add heat to the food. In the spectrum of energy waves, radio waves are at one end of the spectrum, microwaves are in the middle, and the gamma rays of irradiation are at the other end of the continuum. Gamma rays are passed through the food to be irradiated, and the food is thus sterilized and preserved as it passes through an irradiation chamber on a conveyor belt. Scientific evidence demonstrates that foods do not become radioactive and that no radiation residue remains in the food.

Irradiation is a process approved by the FDA, for use with specific foods, and only at designated dosages. Gamma rays are the isotope-sourced form of irradiation, previously mentioned. As well, there is a machine-sourced form of irradiation that is electronically generated. It is known as e-beam (Higgins 2000). Foods that may be irradiated include wheat, potatoes, spices, pork, red meat, fruit, poultry, dehydrated enzymes, or vegetable substances, including fresh produce (and bagged salads). So, in looking at dosages needed for irradiating pork, as an example, it is shown that a *low* dose is required to stop *reproduction* of *Trichinella spiralis* (the parasite responsible for causing trichinosis), and a much *higher* dose is needed in order to *eliminate* it from the pork.

Whole food items must be labeled if they are irradiated. A universal symbol of irradiation, namely the radura symbol, is used for recognition of irradiated food. In the United States, the words "Treated with Radiation" or "Treated by Irradiation" may also appear with the symbol. Spices do not require this labeling. Processed foods that contain irradiated ingredients, or restaurant foods prepared using irradiated ingredients, do not require an irradiation label.

Research has been conducted on the sensory aspects of irradiated food. It is reported that "The sensory appeal of foods which are processed with irradiation at levels that are approved for use is quite good. Researchers who have conducted experimental studies using sensory panelists to evaluate such foods found that food freshness, color, flavor, texture, and acceptability are not significantly different from unirradiated foods" (Texas A&M University—Center for Food Safety). Due to its cold process of food preservation, the nutritive value of irradiated food is not significantly different from food subject to alternate methods of preservation, including canning.

Irradiation preserves food by killing insects and pests. It also kills microorganisms. With regard to food safety, food is made safer by the elimination of disease-causing bacteria such as *E. coli*, *Salmonella*, and the parasite *Trichinella spiralis*. Irradiated food lasts longer and there are reduced losses due to spoilage (Texas A&M University—Center for Food Safety).

Low doses of irradiation may be used to slow fruit ripening and control pests, without the use of pesticides. The process of irradiation leaves no residue.

Food irradiation facilities exist for the irradiation of foods, whereby the food product is sent off-site for treatment. As well, in-line irradiation brings the technology to a company's own production line. A large defense contractor that radiates medical supplies is now using electron beams to pasteurize/irradiate meat, including prepared meats, and other foods (Higgins 2000). A patent was awarded to this corporation for development of a miniature version of their chamber that could incorporate the electronic pasteurization into food producer's processing line. Both cost and convenience issues need to be addressed by a company considering irradiation of its products.

Despite the fact that irradiation of meat and poultry has received the approval of every major government and health agency in the United States, consumer health activists have yet to give their stamp of approval. As a result, meat companies are proceeding at a less than full-steam-ahead rate with irradiation (Gregerson 2001).

The General Accounting Office (GAO) reports to the US House Committee on Commerce have stated that the benefits of irradiation outweigh any risks. "Food safety experts believe that irradiation can be an effective tool in helping to control foodborne pathogens and should be incorporated as part of a comprehensive program to enhance food safety."

Irradiation is subject to FDA approval as an *additive*. Only specific foods, dosages, and irradiation sources are approved to kill microorganisms. “The Food and Drug Administration (FDA) announced a final rule . . . amending the food additive regulations to provide for the safe use of ionizing radiation for the control of foodborne pathogens and extension of shelf-life in fresh iceberg lettuce and fresh spinach. FDA has determined that this use of ionizing radiation will not adversely affect the safety of the food” (FDA).

Ohmic Heating

Ohmic heat processing of foods is relatively new for food manufacturers. In place of radiant heat, an electrical current is passed through food to heat it rapidly. A continuous heating system reaches the food as it passes between electrodes.

Concerning ohmic heating, the *liquid* portion of the food, such as stew or soup, is heated rapidly and it subsequently conducts heat rapidly to the *inner* portion. In comparison, conventional heating tends to overprocesses the surrounding liquid as it conducts heat to the inner portion; consequently, food quality may be diminished.

> What is ohmic heating?
>
> Ohmic heating is an advanced thermal processing method wherein the food material, which serves as an electrical resistor, is heated by passing electricity through it. Electrical energy is dissipated into heat, which results in rapid and uniform heating. Ohmic heating is also called electrical resistance heating, Joule heating, or electro-heating, and may be used for a variety of applications in the food industry.
>
> How is ohmic heating different from conventional thermal processing?
>
> During conventional thermal processing, either in cans or aseptic processing systems for particulate foods, significant product quality damage may occur due to slow conduction and convection heat transfer. On the other hand, ohmic heating volumetrically heats the entire mass of the food material, thus the resulting product is of far greater quality than its canned counterpart. It is possible to process large particulate foods (up to 1 in.) that would be difficult to process using conventional heat exchangers. Additionally, ohmic heater cleaning requirements are comparatively less than those of traditional heat exchangers due to reduced product fouling on the food contact surface. (Ohio State University Extension Fact Sheet. Food Science and Technology)

Induction Heating

Heat may be transferred, or more correctly, generated, by *induction*. Induction is the transfer of heat energy to a neighboring material without contact. This occurs in some smooth cooktops and is a relatively new and therefore fairly expensive technology. Induction involves use of a powerful, high-frequency electromagnet to generate heat in a ferromagnetic (iron or stainless steel) pan on the surface of the cooktop. The heat is then transferred from the pan to the food it contains by normal heat transfer methods.

Induction cooktops all contain an electromagnetic coil beneath the surface. When switched on, alternating current flows through the coil, generating a fluctuating high-frequency electromagnetic field. When a ferromagnetic pan is placed on the cooktop, the electromagnetic field generates many small electric currents, known as eddy currents, in the pan. Because iron is a poor conductor, or in other words has high resistance, these eddy currents are converted to heat. Since heat is generated directly in the pan, and not in the cooktop itself, heating is even—no “hot spots” are generated—and the process is faster and more efficient than the more conventional methods of heating.

As well, the cooktop does not get hot! In addition, it is possible to instantly and precisely control the amount of heat generated in the pan and therefore transferred to the food within it. The only disadvantage of induction cooking is that iron or steel pots and pans must be used; copper, aluminum, or Pyrex pans will not work. However, this is a minor disadvantage, since these types of pans are readily available.

An induction oven has also been produced, where the heating coil has been replaced by a ferrous plate that is heated by embedded induction coils beneath it. This allows for use of any type of bakeware within the oven (http://theinductionsite.com/how-induction-works.shtml).

As the technology progresses, the application of induction cooking is likely to become more widespread and more common.

At this time, televised commercials advertise this method of home stovetop cooking!

High-Pressure Processing

High-pressure processing, or HPP, is a nonthermal processing method that uses physical pressure to preserve food, instead of heat, chemicals, or irradiation. HPP may be used to destroy harmful foodborne pathogens and extend the shelf life of a wide range of foods, without sacrificing sensory characteristics or nutritional quality. Its effect is instantaneous and uniform throughout the product and does not depend on the size or shape of the package.

The process involves subjecting food to extremely high hydrostatic pressure—up to 87,000 lb per square inch (psi)—for a short period of time. The uniform high pressure destroys vegetative bacteria because it disrupts microbial cellular integrity and metabolism. However, it does not destroy bacterial spores (Ramaswamy et al. 2004). Hence, it is useful to prolong shelf life and to reduce bacterial counts and may be used as a pasteurization technique, although it does not sterilize food; after HPP, foods should be refrigerated in order to effectively prolong shelf life. This is especially true of low-acid foods such as vegetables, milk, or soups. HPP can at least double the refrigerated shelf life of many perishable products.

In a typical HPP process, the product is packaged in a flexible container and then placed in a high-pressure chamber which is filled with water. The chamber is pressurized, and the pressure is transmitted through the package into the food itself, usually for a period of 3–5 min. The processed product is then removed and refrigerated. Because the pressure is uniform on all sides, most foods retain their shape and are not squashed or damaged.

HPP does not break covalent bonds in foods, so no free radicals or chemical by-products are formed, and HPP does not "add" anything to food. Hence, neither the FDA nor the Food Safety Inspection Service of the USDA requires approval for high-pressure processing (Raghubeer 2008). Flavor, texture, color, and nutritional quality of food are unaffected by HPP. The process is very effective on foods with high moisture content, such as ready-to-eat meats and poultry (cold cuts), fresh juice, prepared fruit and vegetable products such as salsa and guacamole, and seafood and molluscan shellfish. It is not effective on dry products, since moisture is needed for microbial destruction. Also, it cannot be used on products with internal air pockets, such as bread, or fruits such as strawberries, because the pressure causes them to implode.

HPP is being used extensively by processors for manufacturing of all-natural products in the ready-to-eat meat category, for shucking and shelling of seafood, and for processing preservative-free fruit and vegetable products, juices, and smoothies. HPP-processed products cost more to produce than thermally processed products, yet consumers benefit from the increased shelf life, quality, and availability of value-added products that are impossible to make using other thermal processing methods.

Other Preservation Techniques

The objective of processing is to slow down or stop spoilage that would otherwise exhibit loss of taste, textural quality, or nutritive value. In order to better achieve this, new techniques are constantly being explored.

> People are always looking for ways to increase the shelf life of their food. We have sought out canning, pickling, freezing, adding preservatives, and many other methods to extend the life of our food supply since the beginning of recorded history. Reduced oxygen packaging (ROP) is one of those methods. This method of preservation has many unique advantages, but comes with significant microbiological concerns. (The Association of Nutrition & Foodservice Professionals (ANFP). http://www.anfponline.org/CE/food_protection/2010_11.shtml)

ROP will be covered in the packaging chapter.

Early Methods of Food Preservation

The preservation of harvested and prepared food for future consumption is one of the oldest practical arts, a necessity that developed from the sheer need to survive in a hostile environment where fresh food was not always available. Techniques for drying foods date back to ancient times, when fruits and vegetables were dried in the sun or on an open stove. Without water present, the dehydrated foodstuffs would not support microorganisms and therefore did not spoil. By 1000 BC, the Chinese were using salt, spices and smoking to create a sterile environment for different food products. Salt also acts as a dehydrating agent and is particularly useful for fish and meat. Salted meat served explorers and military forces well because of its stability and portability, and it was a technique that lasted into the twentieth century.

It was also discovered very early that making cheese could preserve dairy products, grape juice could be fermented into wine that would last for years at normal temperatures, and even cabbage could be preserved by converting it to fermented sauerkraut. North American Indians made pemmican by drying the meat of buffalo or deer and then mixing it with a large amount of fat. This was effective because the fat presumably excluded oxygen. (American Chemistry Society (ACS))

Nutritive Value of Preserved Foods

There is no question regarding the importance of preserving factors such as the appearance, texture, and flavor of food. For example, prolonged or improper storage may have a deleterious effect on food due to the browning caused by the Maillard reaction. Still, in a discussion of food preservation and the extension of a food's shelf life, the preservation of nutritive value also becomes important. For instance, water-soluble vitamins may be lost from a food or high levels of sugar or salt may be added. These, and more, become issues to address with regard to nutritive value of preserved foods.

Irradiated fresh produce, such as bagged salad, may now be a healthful addition to the diet for a multitude of persons, including the young, elderly, pregnant, and immunocompromised individuals. The microbial load can be drastically cut, assuring less likelihood of *Shigella* and *E. coli*.

Safety of Preserved Foods

The safety of foods must be taken into account when seeking to store and extend the shelf life of foods. The processor/manufacturer's Good Manufacturing Practices (GMPs), the FDA's inspection, and the consumer's attentiveness all contribute to ensuring that food is properly preserved, stored, and not held beyond acceptable time parameters (See http://www.science.howstuffworks.com/innovation/edible-innovations/food-preservation.htm).

> Because food is so important to survival, food preservation is one of the oldest technologies used by human beings . . .
>
> A food that is **sterile** contains no bacteria. Unless sterilized and sealed, all food contains bacteria. (science.howstuffworks.com)

See FoodSafety.gov:

Some foods are more frequently associated with food poisoning or foodborne illness. With these foods, it is especially important to:

- CLEAN: Wash hands and food preparation surfaces often. And wash fresh fruits and vegetables carefully.
- SEPARATE: Don't cross-contaminate! When handling raw meat, poultry, seafood and eggs, keep these foods and their juices away from ready-to-eat foods.
- COOK: Cook to proper temperature.
- CHILL: At room temperature, bacteria in food can double every 20 min. The more bacteria there are, the greater the chance you could become sick. So, refrigerate foods quickly because cold temperatures keep most harmful bacteria from multiplying.

Conclusion

One aspect of food processing is preservation of the food. Storage conditions and preservation processes are subject to FDA inspection and enforcement. Consumer vigilance is also necessary in order to preserve food. Environmental control of oxygen and water availability and enzymatic control extend shelf life of food and assist in providing food safety.

Techniques of *food preservation* may occur by heating (e.g., cooking, mild heat treatment methods such as blanching or pasteurization, severe heat treatment such as canning or bottling), cold refrigeration, freezing, freeze drying, dehydration, concentrating, microwave heating, high-pressure processing, or other means. These topics appear in this chapter.

Usage of *additives* (Chap. 17) may be employed in preservation—namely preservatives including those used in fermentation, chemical preservation, irradiation (FDA labels this an additive), salt (e.g., salting), sugar, and vinegar (e.g., pickling). As well, preservation may entail *packaging* (Chap. 18), including modifying or removing oxygen as a preservation technique.

Further advances in safe and effective food preservation are on the horizon.

Notes

CULINARY ALERT!

Glossary

Blanching Mild heat treatment that inactivates enzymes that would cause deterioration of food during frozen storage.

Canning An example of a food processing method that involves *severe* heat treatment. Food is placed inside a can, the lid is sealed in place, and the can is then heated in a large commercial pressure cooker known as a retort.

Commercial sterility Severe heat treatment. A sterilization where all pathogenic and toxin-forming organisms have been destroyed as well as all other types of organisms which, if present, could grow in the product and produce spoilage under normal handling and storage conditions.

Concentration Method of removing some of the water from a food, to decrease its bulk and weight. Concentration does not prevent bacterial growth.

Conduction Transfer of heat from one molecule to another molecule; the major method of heat transfer through a solid.

Convection Flow or currents in a heated liquid or gas.

***D* value** Decimal reduction time; time in minutes at a specific temperature required to destroy 90 % of the organisms in a given population.

Dehydration A means of preservation with the primary intent to decrease moisture content and preclude the possibility of microbial growth such as bacteria, mold, and yeast.

Irradiation The administration of measured doses of energy that are product-specific. It reduces the microbial load of a food, kills insects, controls ripening, and inhibits the sprouting of some vegetables.

Ohmic heat In place of radiant heat, a continuous electrical current is passed through food to heat it rapidly, maintaining quality.

Pasteurization Mild heat treatment that destroys pathogenic bacteria and most nonpathogens. It inactivates enzymes and extends shelf life.

Radiation Fastest method of heat transfer; the direct transfer of heat from a radiant source to the food being heated.

Thermal death rate curve Provides data on the rate of destruction of a specific organism in a specific medium or food at a specific temperature.

Thermal death time curve Provides data on the destruction of a specific organism at different temperatures.

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