Lesson 1: Introduction to Food Preservation

America is blessed with an abundance of food. Citizens from a developing country would see more food in one trip to an American grocery store than they would see in a lifetime at home. The United States enjoys the widest variety of healthy foods at the lowest cost relative to income that can be found in the world. Americans enjoy the combination of educated food producers/processors, abundant natural resources, a diverse climate, and advanced food science and technology.

Food scientists have identified the causes of food deterioration. Food technologists have developed techniques to preserve food. The team concept of food science and food technology allows each of us to leave the grocery store with confidence that we have purchased wholesome food.

Why Foods Are Preserved

Food production is often cyclical, while food consumption is more constant. Therefore, foods must be preserved to ensure an abundant supply throughout the year. For a variety of economic, climatic, and political reasons as many as 10,000 people die each day worldwide due to starvation and malnutrition. Food is also preserved in order to prevent microbial growth. A third reason food is preserved is to maintain and enhance its taste and texture by reducing the effects of chemical changes. Also, foods are preserved to provide products in more convenient forms.

Importance of Food Preservation

Ultimately, food preservation is necessary for the preservation of life. Food preservation was also important historically, is presently, and will continue to be in the future. History has shown that early civilizations developed in fertile, food producing areas. Humans learned to sun-dry certain types of foods so they might be eaten at times other than harvest.

Preservation of food was of great importance to Napoleon and his armies. His military campaigns were successful because he provided his troops with adequate food. Napoleon suffered his greatest defeat when it became difficult to feed his troops.

Later it was discovered that salt extended the storage life of foods. Spices and sugar were used as food preservatives by early Asians. American colonists and pioneers depended on salted, pickled, and smoked meat and fish in addition to dried beans. The cold winter temperatures were also useful to process and preserve meats. Lard was melted and spread over cooked sausages for protection. Fruits and vegetables were stored in root cellars, buried, or dried. The cool temperature of the spring house was valuable for storing eggs, milk, and butter.

The 1830's ushered in the railroad, making food transportation over long distances much faster. The refrigerated rail car of the 1880's was revolutionary! The 20th century has witnessed steady progress in food science and technology, which should propel the industry into a bright future.

How will food science and technology impact the future? The world's population continues to expand as the number of food producing acres declines. Therefore, techniques to preserve food will become increasingly important. The demand for convenience will prompt development of new preservation techniques. The added energy expense of refrigeration, freezing, and irradiation could be reduced by new technology. Medical advancements may necessitate other technological developments. Already, food sterilized by irradiation is required by certain chemotherapy patients. Future trends in food science may depend on people like you!

Food Preservation Techniques

Food may be preserved using a variety of techniques.

Heat - Heating food products is a technique used to destroy microorganisms and endogenous enzymes. Most microbial growth occurs between 61°-100°F. Heat-loving (thermophilic) microbes grow in the range of 110°-130°F. In order to destroy these microbes, food products must be heated to an internal temperature greater than 180°F. Heat-enduring (thermoduric) bacteria survive temperatures as high as boiling so food is often canned under pressure to provide a temperature above 212°F. Sterilizing food means heating the food to about 240°F and maintaining that temperature for 15 minutes or longer.

Figure 1.1 - Food Preservation Techniques

- Heat
- Cold
- Drying
- Packaging
- Additives
- Fermentation

Cold - Refrigeration, or maintaining 33°-40°F, is useful to slow microbial growth. Freezing is achieved by reducing the temperature to 0°F or lower, which virtually stops enzymatic action and microbial growth.

Drying - Dehydrating is the removal of moisture to limit microbial and chemical activity. Freeze-drying is the removal of moisture from a frozen food under reduced atmospheric pressure.

Irradiation - Irradiation is a technique that uses gamma rays or beta particles to bombard and kill microbes and inactivate enzymes.

Packaging - Vacuum packaging is the removal of most of the oxygen from food products. This prevents aerobic microbial activity and is usually applied during packaging of refrigerated solid foods. Sometimes an atmosphere rich in CO_2 is used to preserve food, particularly fruits and vegetables. Often the packaging material is very important in creating and maintaining the desired conditions. This type of process is called modified or controlled atmosphere packaging, commonly referred to by the acronym MAP/CAP.

Additives - The use of additives or chemicals to prevent microbial growth is another preservation technique. Sweetening, or achieving a high sugar content, produces a high osmotic pressure which causes water to be withdrawn from microbes. A 70 percent sugar level is necessary to prevent all microbial growth. Salting produces a high osmotic pressure or low water activity (Aw) and restrains microbial growth. Salt levels of 2.5-3.0 percent are common in salt cured food products. Smoking food products allows formaldehyde and phenolic compounds to settle on the food surface. The compounds inhibit microbial growth. Spicing is a technique used to slow the growth of some microbes. However, processors must use spices that are free from undesirable microbial contaminants.

Fermentation - Fermenting, also known as souring or pickling, slows bacterial growth. Acids produce a low pH, which restrict microbial growth. Sometimes, desirable microorganisms are allowed to grow in the food. They convert carbohydrates into acids or alcohol. These by-products inhibit the growth of undesirable microorganisms and provide unique flavors in foods. The use of desirable microorganisms to preserve food is called fermentation. Bacteria convert carbohydrates into acids and alcohol.

Causes of Food Deterioration

Food is subject to physical, chemical, and biological deterioration. In practical terms, food starts deteriorating at the time it is harvested or slaughtered. The critical question becomes: How slow or how rapid is this process? The principle causes of food deterioration are heat, cold, light and other radiation, oxygen, moisture/dryness, natural food enzymes, microorganisms, macroorganisms, industrial contaminants, and time.

Microorganisms, like bacteria, mold, and yeast, ferment sugars and hydrolyze fats, proteins, starches and cellulose. Those that hydrolyze fats produce rancidity. Those that digest proteins make putrid odors. Others produce acid, make food sour, and discolor it. A few produce toxins that can lead to food poisoning.

Natural enzymes can become catalysts of chemical reactions in food. Ripening and tenderizing are examples of natural enzymatic reactions. Some reactions, like the aging of beef or the ripening of tomatoes, are desirable if they are not allowed to continue too far. Tenderizing and ripening beyond an optimal point causes deterioration.

Pests include insects, parasites, birds and rodents. Insects are very destructive to cereal grains, fruits, and vegetables. While an insect may create only a small hole in a melon, this allows microorganisms to invade and cause decay. Freezing, irradiation, and O_2 removal are commonly used to kill insects in food. A common food-borne parasite is Trichinella spiralis. This worm can enter hogs that eat uncooked animal food wastes. If an infected pork carcass is cooked insufficiently, this parasite can enter man. Fish may also harbor parasitic worms that can enter the consumer if the fish is eaten raw.

Rodents, such as rats, not only consume large quantities of stored grain, but also contaminate it with bacteria-infested feces and urine. Flies, rats and cockroaches are all known to transmit disease causing microorganisms to food. For example, rats can transmit salmonellosis, leptospirosis, typhus fever, the plague, and other infectious diseases.

Other Factors - Heat can denature proteins, break emulsions, dry out food, and destroy vitamins. Within the temperature range of 50°-100°F, chemical reaction rates double for every 18°F rise in temperature. These chemical reactions include both enzymatic and non-enzymatic reactions.

Cold temperatures (i.e., below freezing) disrupt the texture and crack the skins of fruits and vegetables. Freezing milk breaks its emulsion and curdles its protein. Temperatures that are too cold cause off-colors, surface pitting, and decay, especially in fresh fruits and vegetables.

Light destroys some vitamins, specifically riboflavin, vitamin A, and vitamin C. It also can cause food discoloration. Ultraviolet light oxidizes milk fat and protein and changes milk's flavor. Not all wavelengths of radiation are absorbed equally. Gold colored filters for fluorescent lights in display cases and opaque packaging are preventative measures.

Moisture or dryness are factors that may contribute to food deterioration. Moisture is required for all microbial growth and for chemical reactions. Too much moisture can cause lumping, crystallization, and stickiness of dried food products. Too little moisture in baked foods can cause dehydration and staleness. Even when fruits and vegetables are placed in a moisture-proof bag, water is given off through respiration and transpiration and the produce shrivels.

Oxygen can have negative effects on vitamins A and C, food color, flavor, and other constituents. Oxygen's presence is essential for mold growth. Oxygen can be removed by deaeration (inert gas purging), vacuum packaging, or flushing containers with nitrogen (N_2) or carbon dioxide (CO_2).

Industrial contaminants are a minor cause of food spoilage. Chemicals may inadvertently come in contact with food and cause discoloration and off-flavors.

Most of these factors are dependent on how long the food is stored. As more time passes, the causes of food deterioration (explained above) are more likely to cause food spoilage. Food quality decreases over time. Two common sense rules of food preservation are: 1) keep food alive as long as possible, and 2) following harvest or slaughter, the product must be cleaned, and preserved as quickly as possible.

Storage Time and Type Affects Food Quality

The type of storage affects food quality. Of course, food needs to be wholesome in the beginning. How the product was handled immediately following harvest also directly affects food shelf life (the time it is satisfactory to eat). Most fruits and vegetables need a refrigeration unit in the field at the time of harvest. The shorter the time required to cool food products to 33°-40°F, the longer they can be stored. For example, sweet corn will metabolize its own sugar (convert its own sugar into starch) following harvest. At 32°F only 10 percent of its sugar will be converted to starch in one day. At 68°F 25 percent of its sugar may be converted in one day. The use of portable hydrocoolers that jet spray fresh produce with cold water is highly beneficial. The water may contain a germicide to inactivate surface microbes. Nitrogen gas can also be used to induce evaporative cooling. Animal carcasses must be cooled to an internal temperature of 36°F within 24 hours of slaughter.

Another critical factor affecting long-term storage is the relative humidity (RH) during storage and handling. Most microorganisms thrive in moist environments. Therefore, relative humidity levels must be carefully controlled. Underground caves used for food storage provide a fairly static and low RH. Insufficient moisture can also cause dehydration of food. Beef stored at less than 90 percent RH dries out. If RH is between 90-98 percent, the beef will mold. If above 98 percent, the bacteria will cause spoilage. Meat tissue may be covered with a film of plastic to decrease moisture loss. Cheeses can be wrapped in impermeable films to prevent drying out. Eggs may be coated with a thin firm of mineral oil to maintain desirable moisture levels.

Refrigeration refers to temperatures of 30°-61°F. Most foods may be preserved for days to weeks at these temperatures. Freezing temperatures are below 30°F. Foods can be preserved for months to years. Neither refrigeration nor freezing completely destroys all microbes. Once food is thawed, rapid microbial growth is possible. Refrigeration is one of the gentlest methods of food storage in terms of maintaining taste, nutritive value, and texture. Refrigeration accelerates the staling of breads. Food stored long-term must be sterilized, dehydrated, irradiated, fermented, or completely frozen.

Summary

Food preservation is necessary to maintain human life. We preserve food for human safety, quality enhancement, convenience, and to maintain an adequate supply. Food preservation will be as important in the future as it has been in the past. Controlling microbes and enzymatic activity are the goals of a variety of preservation techniques. If these techniques are not used, physical, chemical, and biological deterioration are possible. The time and method of food storage are other major factors that influence food quality.

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Lesson 2: Food Perishability

Food is a perishable commodity. The storage life, however, depends on a variety of factors as well as which food product you are considering. Egyptians stored wheat very well. Recently, some Egyptian wheat stored for more than 3,000 years was discovered. This wheat was still suitable for use as food. Other products, like fresh, uncooked meat can spoil within a few hours if left at room temperature.

Food Characteristics Influence Deterioration Rate

Deterioration rate is influenced by the characteristics of the food product. The pH, or hydrogen ion concentration, affects how long food will stay fresh. In general, foods spoil fastest when pH lies between 6 and 8 (Neutral pH is 7.0).

The moisture, or water activity level, is another important food characteristic that influences deterioration rate. All microorganisms require moisture to survive. Foods with very little water content will not support microbial growth. The water activity level of foods must be reduced to 0.6 or below to prevent all microbial growth. Foods with a water activity near .99 support microbial growth best. Moisture may be removed by heating the food or by adding salt or sugar to the food, which by the process of osmosis, removes water from the microbe's cytoplasm.

Deterioration rate is also affected by the temperature of the product. Foods deteriorate fastest at temperatures between 60°F and 100°F.

The oxygen level of the food product is another important consideration. If the oxygen has been removed from the food by vacuum packaging, the growth of molds and aerobic bacteria will be stopped, but anaerobic microorganisms may flourish.

The physical characteristics of the food are also factors that influence deterioration rate. The degree of ripeness, whether immature or overmature, can have a dramatic effect on the food's perishability rate. The actual size of the product, or its surface area, is another important physical characteristic. In the case of meat, the whole carcass is less vulnerable to deterioration than steaks or ground meat because the whole carcass has less exposed surface area per unit of weight or volume. Because retail cuts such as steaks have more surface area, they provide a more readily available source of nutrients, oxygen, and water for the microbes than do whole carcasses.

Acidity/Alkalinity Influence on Perishability of Foods

The pH readings of most foods vary from about 2.6 to 7.0. Some examples are: dill pickles, pH 2.9; apples, pH 3.0; tomatoes, pH 4.2; sweet potatoes, pH 5.4; and shrimp, pH 6.9. The perishability of food products is dependent upon their degree of acidity or alkalinity. On the pH scale of 0-14, an alkali is any substance with a pH of 7.1-14.0. An acid has a pH of 0-6.9. Alkalis have a bitter taste; therefore, very few food products are alkaline. Stored eggs and soda crackers are examples of alkaline foods.

Figure 2.1 - pH Scale

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1  2  3  4  5  6  7  8  9 10 11 12 13 14
|__|__|__|__|__|__|__|__|__|__|__|__|__|
|                 |                    |
Acidic         Neutral          Alkaline
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An alkaline pH reading above about 8.0 slows or inhibits microbial growth. An acid modifies or denatures bacterial protein, and some acids are directly toxic to bacteria. Therefore, the more acidic a food product is, the slower its rate of deterioration will be. Acids are natural products of citrus, apples, tomatoes, etc. Acids can also be added. In the case of pickling, acetic acid may be added. Lactic acid is the product of bacteria that is native or has been added in fermentation. Microorganisms prefer an environment with a pH range of 2.0-8.0. Bacteria favor a neutral pH, molds prefer 2.0-8.0, and yeasts prefer 4.0-4.5.

Relationship Between Water, Salt, Sugar, and Osmotic Pressure

Water is required by all microorganisms. A reduction in the amount of water available is an effective means of food preservation. All of the moisture in a food product may not be available to the microorganisms. The amount of water that is available is called water activity (Aw). When salt or sugar is added to food, the Aw decreases. This is the principle used for salt or sugar-curing meat and also for syrup, jelly, and jam making. The addition of salt or sugar increases the osmotic pressure of the food item. Osmotic pressure is defined as the force that a dissolved substance (e.g., salt or sugar) places on a semipermeable membrane through which it cannot penetrate when the dissolved substance is separated from pure water by that membrane. When the osmotic pressure in a food product is high enough to draw water away from a microbial cell or prevent normal diffusion of water into the microbial cell, the cytoplasm of that cell dehydrates. This is fatal to that microbe. The greater the salt or sugar concentration is, the higher the osmotic pressure will be. A 70 percent sucrose solution will stop the growth of all food microbes.

Microbial Activity

Microbial activity affects food preservation both physically and chemically. Physical changes of food are more apparent than chemical changes. Slime formation, undesirable odors and flavors, and color changes are all physical changes caused by aerobic bacteria and yeasts. Aerobic means in the presence of O_2. Another physical change caused by aerobic molds is a sticky surface.

Chemical changes in food caused by microbial activity include the breakdown of complex organic molecules into simpler molecules. Examples include protein decomposition into peptides and amino acids under aerobic conditions. When anaerobic (without the presence of O_2) conditions are present, proteins are degraded into foul-smelling sulfur compounds. Non-protein nitrogen is degraded into ammonia. Microbes secrete lipases which hydrolyze, i.e., break down by adding water (H_2O), molecules of triglycerides into glycerol and fatty acids. Similarly, phospholipases hydrolyze phospholipids. This process creates a rancid flavor in food. Carbohydrates, the preferred energy source of microorganisms, are broken into organic acids, alcohol, CO_2 and H_2O, depending on the pathway the microorganism uses in metabolizing them. Lactic acid in fermented sausage is an example of an organic acid. Microorganisms, after degrading complex molecules, utilize the simpler molecules as nutrient sources for their growth and activity.

Chemical Preservatives

Chemical preservatives are substances added to a food intentionally to improve its appearance, flavor, texture, or storage properties. They are often called additives. One example of an additive is sodium benzoate, which is used to prevent microbial growth in soft drinks and acidic foods. Calcium and sodium propionates are additives used in breads and cakes to prevent mold growth. Cheese products may have sorbic acid added to control mold. Fruits and vegetables may be washed in a germicidal chlorine compound. Ethylene oxide and ethylene formate are fumigants used to control microbes of spices, nuts, and dried fruits. Sulfur dioxide (SO_2), is an additive which controls the browning of fruits and vegetables.

Many foods which contain fat become rancid by oxidation. Therefore, BHA (butylated hydroxyanisole), BHT (butylated hydroxytoluene), and TBQH (tertiary butylated hydroquinone) are used in products like potato chips to prevent oxidation. Nitrites are often used in cured meats to help prevent outgrowth of *Clostridium botulinum*. Salt or sugar used to lower the Aw and acid needed to lower the pH are considered additives. The addition of smoke, another additive, acts as a bacteriostat or bactericide.

Atmosphere Affects Food Perishability

Food perishability is affected by the gaseous atmosphere. In the absence of O_2, all molds and aerobic bacteria are controlled. Nitrogen is used in immersion freezing. Nitrous oxide is a propellant used in aerosol food cans. Carbon dioxide (CO_2) replaces the O_2 in fermented products. CO_2 is also used in soft drinks where it contributes to carbonic acid production. CO_2 and ozone (O_3), have been used in the holds of ships to prevent aerobic microbial growth. Ethylene gas speeds the ripening and color development in citrus and bananas. Eggs are stored in enriched CO_2 storehouses to minimize micro growth. The relative humidity levels in the gaseous atmosphere also affect the rate of spoilage of foods.

Summary

The deterioration rate of food is influenced by the type of product, pH, water activity, temperature, oxygen level, and many physical and chemical characteristics. The more acidic a food product, the slower the deterioration rate. The addition of salt or sugar to food will increase the osmotic pressure and lower the water activity, and hence the deterioration rate decreases. Microbial activity causes both physical and chemical changes in food. For this reason, food additives are often used to intentionally improve a food's storage properties. A wide variety of gaseous atmospheres can be used to help preserve food products.

Credits

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