EXPERT REVIEWED

Food Preservation Methods

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Foods are freshest and at optimum quality at the time of their harvest or slaughter. To maintain this quality in foods that will be consumed later, the foods can be preserved by cold, heat, chemical preservatives, or combinations of these methods. Cold usually means refrigeration or freezing. Heating involves many processing methods, such as pasteurization, commercial sterilization, and drying. Adding preservative ingredients and processing by means of fermentation are also ways to preserve foods.

A food entrepreneur needs a basic understanding of the various preservation techniques before starting a business.

Food processing converts harvested or raw foods into forms that are more easily stored and consumed, and sometimes into a form that may be more desirable. For example, wheat is processed into flour, which is used to make bread and pasta. Strawberries can be processed into freeze-dried berries for use in cereals or cooked to create strawberry preserves.

Foods can be generally classified as cereals, fruits, vegetables, dairy, and meats. Different food types are preserved and processed in various ways to extend the period of time during which the food can be shipped, displayed in the store, purchased by the consumer, and finally consumed. The physical and chemical composition of the food helps determine the type of process required for preservation. Other factors that influence a choice of preservation method are the desired end product, type of packaging, cost, and distribution methods.

The Role of Water Activity and Acidity in Preservation

The two most important chemical composition factors that affect how a food is preserved are water content and acidity. ***Water content*** includes moisture level, but an even more important measurement is water activity. ***Water activity*** (a_w) refers to the energy status of water in the food, which affects whether or not chemical reactions occur and/or microorganisms will grow. The content of the food—such as sugar, salt, protein, or starch—"binds" the water, making it less available. Foods with lower water activities are less prone to spoilage by microorganisms and have fewer undesirable chemical changes occur during storage.

Water activity levels for growth of microorganisms

a_w	Microorganisms that grow at this water activity level
0.95	*Salmonella* spp., *Pseudomonas, Escherichia coli, Bacillus cereus,* some yeasts
0.90	*Clostridium botulinum, Lactobacillus, Listeria monocytogenes, Clostridium perfringens*
0.87	Yeasts, *Staphylococcus aureus*
0.80	Molds, *Saccharomyces* spp.
0.60	Some yeasts and molds

Water activity levels of common foods

a_w range	Food
0.95–0.99	Fresh meat, fish
0.90–0.95	Bread
0.85–0.95	Cheese
0.80–0.91	Jams
0.75–0.90	Honey, syrups
0.60–0.90	Cakes, pastry
0.60–0.75	Dried fruits
0.20–0.35	Crackers

The water activity of pure water is 1.0 (or 100% relative humidity). A dry cracker has a water activity of about 0.2, and jam has a water activity of about 0.85. A low level for water activity indicates less free water in the food. Neither *Staphylococcus aureus* nor any other pathogen can grow at a water activity level of 0.85 or below.

Acidity refers to pH, or level of hydrogen ions, which is measured on a scale of 0–14. Products with a low pH (below 7.0) are ***acidic***, and products with a high pH (above 7.0) are ***alkaline (basic)***. For example, tomatoes have a pH range of 4.1–4.9, so they are acidic. Egg whites have a pH range of 7.6-9.6, so they are alkaline. A pH of 7.0 is considered ***neutral***; water has a pH of 7.0. A pH level below 4.6 inhibits the production of a deadly toxin produced by *Clostridium botulinum*, which causes botulism.

pH levels for growth of microorganisms

pH range of growth	Microorganism
5.5–8.0	*Clostridium perfringens*
4.9–9.3	*Bacillus cereus*
4.6–9.5	*Escherichia coli*
4.5–9.0	*Salmonella* spp.
4.2–9.0	*Clostridium botulinum*
4.2–9.3	*Staphylococcus aureus*

pH levels of common foods

pH range	Food
7.1–7.9	Eggs
6.3–8.5	Milk
5.3–5.8	Bread
5.0–7.0	Meats
4.8–7.3	Fish
4.0–7.0	Vegetables
3.3–7.1	Fruits
3.1–4.5	Berries

Federal and state food regulations specify that a shelf-stable product that does not require refrigeration or does not undergo sufficient heat treatment must have a water activity equal to or below 0.85 or a natural pH equal to or below 4.6. Various changes can be made to product recipes in order to reach the target water activity and/or pH level. For example, adding sugar or salt to a product can lower its water activity. And adding acid—in the form of vinegar or lemon juice can reduce pH. Reducing the water activity below 0.85 or acidifying a food to reach a pH level of 4.6 or lower will prevent the growth of harmful bacteria. Adding preservative compounds—such as sodium benzoate (to prevent bacteria and yeast growth) or potassium sorbate (to prevent yeast and mold growth)—can also aid in the preservation process.

Preservation Techniques

Foods are often preserved with a combination of formulation (added ingredients), processing (heating or cooling), and distribution methods (shelf stable, refrigeration, freezing). When choosing the best method for preserving a product, food processors must pay close attention to the pH and water activity while also considering how a preservation technique will affect the quality of the finished product.

Preservation techniques commonly used for food processing are outlined below. More detailed descriptions of these commercial processing methods can be found in textbooks.

Refrigerating

Potentially hazardous foods, or those foods with a pH greater than 4.6 and water activity greater than 0.85, must be kept below 40˚F. These foods include cooked meat and poultry, milk and dairy products, eggs, products made with eggs, shellfish, and seafood. Foods that cannot be dried or canned or that need to maintain a fresh quality are also preserved by refrigeration. Examples are perishable fruits and vegetables, meat and poultry, cheese, yogurt, fresh salsa, and soy milk. These products have a limited shelf life because refrigeration only slows bacterial growth; it does not prevent it. Mishandling during shipment and by the consumer can increase the rate of bacterial growth and should be accounted for in shelf-life determination. Additionally, these products have a higher warehousing and shipping cost because of the need to maintain proper refrigeration. However, these products have high appeal to consumers because they are fresh and convenient.

Freezing

Freezing can be used to preserve a number of food products. Commercially frozen food is stored at -10˚F to 20˚F. Freezing halts bacterial growth, but does not eliminate bacteria. If processed carefully, a frozen food product will maintain quality in color, texture, and flavor for a long shelf life. Frozen foods, such as large cuts of meat that require thawing, are less convenient than fresh foods. However, consumers perceive food items such as frozen meals and desserts as more convenient than making them from scratch at home. In addition, frozen fruits and vegetables are perceived as being fresher than canned. As with refrigeration, commercially frozen foods have the disadvantage of higher storage and distribution costs in addition to the energy costs to initially freeze the food product.

Drying (Traditional, Freeze-Dry, Spray-Dry)

Dehydrated foods have a long shelf life because removal of moisture lowers the water activity to below 0.50 so that spoilage organisms cannot grow. Fruits and vegetables can be dried and sold as is, or they can be used in other dry products that have a long shelf life, such as cereal or granola bars. Traditional drying of foods utilizes heat, air, and time in various processes that allow removal of moisture to a desired level. Freeze-drying is a form of dehydration in which the product is frozen and water is removed as vapor. Spray-drying is a method that rapidly dries a liquid slurry by spraying small droplets into a heated chamber. Milk that undergoes spray-drying is sold as powdered milk that can be reconstituted. The reduction of moisture content by heat treatment in drying can be expensive, depending on the time required. Additionally, there is usually some loss of product quantity and quality associated with any drying method.

Pasteurizing

Pasteurization uses heat treatment for a short time to destroy harmful microorganisms that might be in a food without adversely affecting the food's flavor and color. This process is done to ensure the treated food is safe for human consumption. Pasteurization is most commonly used on liquids such as milk and juices, with raw milk being the most common pasteurized food. High-temperature/short-time pasteurized milk is heated for 15 seconds at 161˚F. Ultra-high-temperature pasteurized milk is heated for 2 seconds at 280˚F. These different time/temperature treatments for milk are equally effective at reducing harmful bacteria and many spoilage microbes. In addition to making a product safer for human consumption, pasteurization also increases product shelf life. Most pasteurized products are stored under refrigeration conditions and are not shelf stable.

Pasteurization Methods

Product	Temperature	Time
Milk	145˚F	30 min.
	161˚F	*15 sec.*
	280˚F	2 sec.
Juice	155˚F	30 min.
	180˚F	15 sec.
Egg in shell	130˚F	45 min.

Note: Italics indicate most common pasteurization method for milk.

Thermal Processing (Low-Acid Canned Foods)

Foods that are stored at room temperature and sold in a sealed container (metal, glass, or plastic laminate pouch) are heat processed to destroy microorganisms that can either spoil the food or cause a health hazard. These thermally processed foods are called "commercially sterile"—or, more commonly, "shelf stable." The time and temperature needed to make a food shelf stable depends on several factors, including the pH and physical nature

When doing any type of thermal processing, it is important to verify the final temperature of the product. Here a kitchen manager checks the temperature of a product being cooked in a steam-jacketed kettle.

Product characterization	pH (all products have water activity greater than 0.85)	FDA regulations	Example
Acidic	natural pH equal to or less than 4.6		lemons
Acidified	formulated pH equal to or less than 4.6	21 CFR 108.25 21 CFR 114	tomato salsa with green peppers & onions
Low-Acid	pH greater than 4.6	21 CFR 108.35 21 CFR 113	canned green beans

Note: Some exceptions do exist in these regulations. Please refer to the Code of Federal Regulations for more information about these exceptions.

of the food, type of container, and size of container. For example, low-acid canned foods (those with a pH greater than 4.6 and water activity greater than 0.85) need to be heated at a high temperature (240°F) to ensure destruction of *Clostridium botulinum.* In most cases a pressurized cooker is required to reach such high temperatures.

Before manufacturing low-acid canned foods, the food processor must meet U.S. Food and Drug Administration (FDA) regulations. See "Registering Food Processes and Facilities with the U.S. Food and Drug Administration" (*below*) for more information.

Acidifying (Acidified Foods)

Adding acid to a product with a initial pH greater than 4.6 in order to reduce it below 4.6 is called ***acidification***. This results in an ***acidified food***. Low-acid fruits and vegetables (those with a pH greater than 4.6) are often preserved by acidification.

Cucumbers can be preserved by a fermentation or non-fermentation process, both of which acidify the cucumbers and prevent the growth of harmful bacteria.

Acidified fruits and vegetables (sometimes referred to as "pickled foods") can be either fermented or non-fermented. ***Fermented*** products are those with an initial pH greater than 4.6 that are placed in a brine (saltwater) solution in which bacteria (native or added culture) convert carbohydrates to acid. This acidifies the product, making it shelf stable without refrigeration. Sauerkraut is an example of a traditionally fermented food. ***Non-fermented*** products are acidified by adding acid—for example, vinegar or citric acid—to the product. In the past, the majority of acidified foods were fermented in the home, but as demand grew for a large, consistent food supply, the direct addition of acid has become more common. This allows food processors to increase quality, consistency, and manufacturing speed. Some common non-fermented products widely available today are pickled beets and dill pickles (cucumbers that have been pickled.

Depending on the microorganisms used in fermentation (i.e., bacteria and/or yeast), carbohydrates are converted into acids, gas, or alcohol. Thus, fermentation is not solely used on low-acid fruits and vegetables. Fermentation is also commonly used to produce dairy products – yogurt and cheese – as well as beer and wine, but be aware that these products are subject to different regulations than other acidified foods.

Before manufacturing acidified foods that are not refrigerated, the food processor must meet U.S. Food and Drug Administration (FDA) regulations. See "Registering Food Processes and Facilities with the U.S. Food and Drug Administration" (*below*) for more information.

Registering Food Processes and Facilities with the U.S. Food and Drug Administration

In order to begin processing low-acid canned foods or acidified foods, a food processor must first register the processing location with the U.S. Food and Drug Administration (FDA) and submit for review a Form 2541 showing the ***scheduled process***, or food-processing conditions. Prior to this filing, it is recommended that the scheduled process be reviewed by a ***process authority***, which is an individual or group of professionals recognized by the FDA to have specific expertise in the methods used for food preservation. In addition, the processor must attend an FDA-approved Better Process Control School.

Scheduled processes may now be filed electronically, so the processor can track the status of their submission. Filing of a scheduled process with FDA for an acidified or low-acid product does not constitute approval by FDA. It is the responsibility of the processor to determine and assure that the process used adequately meets food-safety requirements before product use. For more information, visit this website: http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/AcidifiedLow-AcidCannedFoods/EstablishmentRegistrationThermalProcessFiling/Instructions/ucm2007436.htm

References

U.S. Food and Drug Administration

Foodborne Pathogenic Microorganisms and Natural Toxins Handbook, www.fda.gov/food/foodsafety/foodborneillness/foodborneillnessfoodbornepathogensnaturaltoxins/badbugbook/default.htm

Acidified and Low-Acid Canned Foods Guidance for Industry, http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/AcidifiedandLow-AcidCannedFoods/default.htm

U.S. Department of Agriculture

Refrigeration and food safety, www.fsis.usda.gov/Fact_Sheets/Refrigeration_&_Food_Safety/index.asp

Additional Resources

Garbutt, John. *Essentials of Food Microbiology.* London: Hodder Headline Group, 1997.

Hurst, William C., A. Estes Reynolds, George Schuler, and P.T. Tybor. “Getting Started in the Specialty Food Business” (Extension Bulletin 1051). University of Georgia College of Agriculture and Environmental Sciences, 1997.

Smith, Durward, and Jayne E. Stratton. “Understanding GMPs for Sauces and Dressings” (Extension Publication G1599). University of Nebraska-Lincoln Extension, 2006.

For more information, please refer to other publications in the* Food Entrepreneurship Series*:

FS-14-W, Organic Foods

FS-16-W, Regulations for Indiana Food Processing

FS-17-W, Using an Approved Kitchen to Prepare Food for Sale

FS-18-W, Using a Home Kitchen to Prepare Food for Sale

All of these publications are available at the ***Purdue Extension Education Store***, www.the-education-store.com.

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