Pasteurization

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Cream pasteurizing and cooling coils at Murgon Butter Factory, 1939

Pasteurization or **pasteurisation**[1] is a process that kills microbes (mainly bacteria) in food and drink, such as milk, juice, canned food, and others.

It was invented by French scientist Louis Pasteur during the nineteenth century. In 1864 Pasteur discovered that heating beer and wine was enough to kill most of the bacteria that caused spoilage, preventing these beverages from turning sour. The process achieves this by eliminating pathogenic microbes and lowering microbial numbers to prolong the quality of the beverage. Today, pasteurisation is used widely in the dairy industry and other food processing industries to achieve food preservation and food safety.[2]

Unlike sterilization, pasteurization is not intended to kill all microorganisms in the food. Instead, it aims to reduce the number of viable pathogens so they are unlikely to cause disease (assuming the pasteurized product is stored as indicated and is consumed before its expiration date). Commercial-scale sterilization of food is not common because it adversely affects the taste and quality of the product. Certain foods, such as dairy products, may be superheated to ensure pathogenic microbes are destroyed.[3]

Contents

Pasteurization conditions

Minimum pasteurization requirements for milk products are shown in Table 1 below, and are based on regulations outlined in the Grade A Pasteurized Milk Ordinance (PMO).[4] These conditions were determined to be the minimum processing conditions needed to kill Coxiella burnetii, the organism that causes Q fever in humans, which is the most heat resistant pathogen currently recognized in milk. Milk can be pasteurized using processing times and temperatures greater than the required minimums.

Pasteurization can be done as a batch or a continuous process. A vat pasteurizer consists of a temperature-controlled, closed vat. The milk is pumped into the vat, the milk is heated to the appropriate temperature and held at that temperature for the appropriate time and then cooled. The cooled milk is then pumped out of the vat to the rest of the processing line, for example to the bottling station or cheese vat. Batch pasteurization is still used in some smaller processing plants. The most common process used for fluid milk is the continuous process. The milk is pumped from the raw milk silo to a holding tank that feeds into the continuous pasteurization system. The milk continuously flows from the tank through a series of thin plates that heat up the milk to the appropriate temperature. The milk flow system is set up to make sure that the milk stays at the pasteurization temperature for the appropriate time before it flows through the cooling area of the pasteurizer. The cooled milk then flows to the rest of the processing line, for example to the bottling station. There are several options for temperatures and times available for continuous processing of refrigerated fluid milk. Although processing conditions are defined for temperatures above 200 °F, they are rarely used because they can impart an undesirable cooked flavor to milk.

Alcoholic beverages

The process of heating wine for preservation purposes has been known in China since 1117,[5] and was documented in Japan in the diary *Tamonin-nikki*, written by a series of monks between 1478 and 1618.

Much later, in 1768, an Italian priest and scientist Lazzaro Spallanzani proved experimentally that heat killed bacteria, and that they do not reappear if the product is hermetically sealed.[6] In 1795, a Parisian chef and confectioner named Nicolas Appert began experimenting with ways to preserve foodstuffs, succeeding with soups, vegetables, juices, dairy products, jellies, jams, and syrups. He placed the food in glass jars, sealed them with cork and sealing wax and placed them in boiling water.[7] In that same year, the French military offered a cash prize of 12,000 francs for a new method to preserve food. After some 14 or 15 years of experimenting, Appert submitted his invention and won the prize in January 1810. Later that year,[8] Appert published *L'Art de conserver les substances animales et végétales* (or *The Art of Preserving Animal and Vegetable Substances*). This was the first cookbook of its kind on modern food preservation methods.[9][10]

La Maison Appert (English: The House of Appert), in the town of Massy, near Paris, became the first food-bottling factory in the world,[7] preserving a variety of food in sealed bottles. Appert's method was to fill thick, large-mouthed glass bottles with produce of every description, ranging from beef and fowl to eggs, milk and prepared dishes. His greatest success for publicity was an entire sheep. He left air space at the top of the bottle, and the cork would then be sealed firmly in the jar by using a vise. The bottle was then wrapped in canvas to protect it, while it was dunked into boiling water and then boiled for as much time as Appert deemed appropriate for cooking the contents thoroughly. Appert patented his method, sometimes called *appertisation*.in his honor.

Appert's method was so simple and workable that it quickly became widespread. In 1810, British inventor and merchant Peter Durand, also of French origin, patented his own method, but this time in a tin can, so creating the modern-day process of canning foods. In 1812, Englishmen Bryan Donkin and John Hall purchased both patents and began producing preserves. Just a decade later, Appert's method of canning had made its way to America.[11] Tin can production was not common until the beginning of the 20th century, partly because a hammer and chisel were needed to open cans until the invention of a can opener by an inventor named Yates in 1855.[7]

Appert's preservation by boiling involved heating the food to an unnecessarily high temperature, and for an unnecessarily long time, which could destroy some of the flavor of the preserved food.

A less aggressive method was developed by the French chemist Louis Pasteur during an 1864[6] summer holiday in Arbois. To remedy the frequent acidity of the local wines, he found out experimentally that it is sufficient to heat a young wine to only about 50–60 °C (122–140 °F) for a brief time to kill the microbes, and that the wine could subsequently be aged without sacrificing the final quality.[6] In honour of Pasteur, the process became known as "pasteurization" [12] Pasteurization was originally used as a way of preventing wine and beer from souring,[13] and it would be many years before milk was pasteurized. In the United States in the 1870s, it was common for milk to contain substances intended to mask spoilage before milk was regulated.[14]

Milk

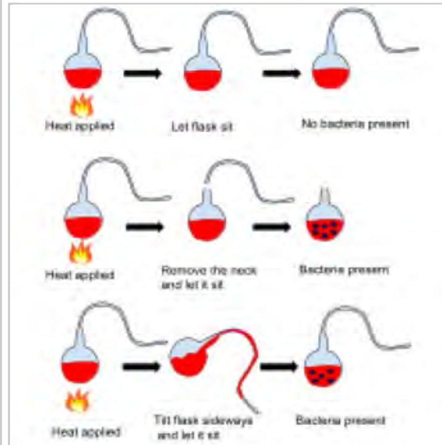

400 lbs of milk in cheese vat

Milk is an excellent medium for microbial growth,[15] and when stored at ambient temperature bacteria and other pathogens soon proliferate.[16]

The US Centers for Disease Control (CDC) says improperly handled raw milk is responsible for nearly three times more hospitalizations than any other food-borne disease source, making it one of the world's most dangerous food products.[17][18] Diseases prevented by pasteurization can include tuberculosis, brucellosis, diphtheria, scarlet fever, and Q-fever; it also kills the harmful bacteria *Salmonella*, *Listeria*, *Yersinia*, *Campylobacter*, *Staphylococcus aureus*, and *Escherichia coli* O157:H7,[19][20] among others.

Pasteurization is the reason for milk's extended shelf life. High-temperature, short-time (HTST) pasteurized milk typically has a refrigerated shelf life of two to three weeks, whereas ultra-pasteurized milk can last much longer, sometimes two to three months. When ultra-heat treatment (UHT) is combined with sterile handling and container technology (such as aseptic packaging), it can even be stored unrefrigerated for up to 9 months.

History



Louis Pasteur’s pasteurization experiment illustrates the fact that the spoilage of liquid was caused by particles in the air rather than the air itself. These experiments were important pieces of evidence supporting the idea of Germ Theory of Disease.

Before the widespread urban growth caused by industrialization, people kept dairy cows even in urban areas and the short time period between production and consumption minimized the disease risk of drinking raw milk.[21] As urban densities increased and supply chains lengthened to the distance from country to city, raw milk (often days old) became recognised as a source of disease. For example, between 1912 and 1937 some 65,000 people died of tuberculosis contracted from consuming milk in England and Wales alone.[22] In the early 1900s, in Arizona, Jane H. Rider "publicized the link between infant mortality and contaminated milk, and finally convinced the dairy industry to pasteurize milk."

Developed countries adopted milk pasteurization to prevent such disease and loss of life, and as a result milk is now widely considered one of the safest foods.[21] A traditional form of pasteurization by scalding and straining of cream to increase the keeping qualities of butter was practiced in England before 1773 and was introduced to Boston in the US by 1773,[23] although it was not widely practiced in the United States for the next 20 years. It was still being referred to as a "new" process in American newspapers as late as 1802.[24] Pasteurization of milk was suggested by Franz von Soxhlet in 1886.[25] In the early 20th century, Milton Joseph Rosenau, established the standards (i.e. low temperature, slow heating at 60 °C (140 °F) for 20 minutes) for the pasteurization of milk,[26][27] while at the United States Marine Hospital Service, notably in his publication of The Milk Question (1912).[28] States in the U.S.A. began enacting mandatory dairy pasteurization laws with the first in 1947, and in 1973 the U.S. Federal Government required pasteurization of milk used in any interstate commerce.[29]

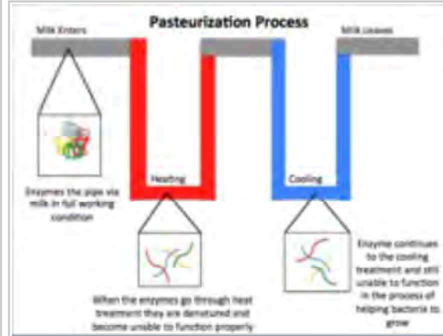
Process

Older pasteurization methods used temperatures below boiling, since at very high temperatures, micelles of the milk protein casein irreversibly aggregate, or *curdle*. Newer methods use higher temperature, but shorten the time. Among the pasteurization methods listed below, the two main types of pasteurization used today are high-temperature, short-time (HTST, also known as "flash") and extended shelf life (ESL):

- HTST milk is forced between metal plates or through pipes heated on the outside by hot water, and the milk is heated to 72 °C (161 °F) for 15 seconds.[30]:8 Milk simply labeled "pasteurized" is usually treated with the HTST method.
- UHT, also known as ultra-heat-treating, processing holds the milk at a temperature of 140 °C (284 °F) for four seconds.[31] During UHT processing milk is sterilized and not pasteurized. This process lets consumers store milk or juice for several months without refrigeration. The process is achieved by spraying the milk or juice through a nozzle into a chamber filled with high-temperature steam under pressure. After the temperature reaches 140 °C the fluid is cooled

instantly in a vacuum chamber, and packed in a pre-sterilized airtight container.[31] Milk labeled "ultra-pasteurized" or simply "UHT" has been treated with the UHT method.

- ESL milk has a microbial filtration step and lower temperatures than UHT milk.[32] Since 2007, it is no longer a legal requirement in European countries (for example in Germany) to declare ESL milk as ultra-heated; consequently, it is now often labeled as "fresh milk" and just advertised as having an "extended shelf life," making it increasingly difficult to distinguish ESL milk from traditionally pasteurized fresh milk.
- A less conventional, but US FDA-legal, alternative (typically for home pasteurization) is to heat milk at 63 °C (145 °F) for 30 minutes.[33]



General overview of the pasteurization process. The milk starts at the left and enters the piping with functioning enzymes that, when heat treated, become denatured and stop the enzymes from functioning. This helps to stop pathogen growth by stopping the functionality of the cell. The cooling process helps stop the milk from undergoing the Maillard reaction and caramelization. The pasteurization process also has the ability to heat the cells to the point that they burst from pressure build up.

Pasteurization methods are usually standardized and controlled by national food safety agencies (such as the USDA in the United States and the Food Standards Agency in the United Kingdom). These agencies require that milk be HTST pasteurized to qualify for the pasteurized label. Dairy product standards differ, depending on fat content and intended usage. For example, pasteurization standards for cream differ from standards for fluid milk, and standards for pasteurizing cheese are designed to preserve the enzyme phosphatase, which aids cutting. In Canada, all milk produced at a processor and intended for consumption must be pasteurized, which legally requires that it be heated to at least 72 °C for at least 16 seconds,[34] then cooling it to 4 °C to ensure any harmful bacteria are destroyed. The UK Dairy Products Hygiene Regulations 1995 requires that milk be heat treated for 15 seconds at 71.7 °C or other effective time/temperature combination.[35]

Some older references[36] point to one or multiple cycles of heating and cooling (to ambient temperature or below) as either a definition of pasteurisation or a general method thereof.[36]

A process similar to pasteurization is thermization, which uses lower temperatures to kill bacteria in milk. It allows a milk product, such as cheese, to retain more of the original taste, but thermized foods are not considered pasteurized by food regulators.[33]

Microwave volumetric heating

Microwave volumetric heating (MVH) is the newest available pasteurization technology. It uses microwaves to heat liquids, suspensions, or semi-solids in a continuous flow. Because MVH delivers energy evenly and deeply into the whole body of a flowing product, it allows for gentler and shorter heating, so that almost all heat-sensitive substances in the milk are preserved.[37]

Efficiency

The HTST pasteurization standard was designed to achieve a five-log reduction, killing 99.999% of the number of viable micro-organisms in milk.[38] This is considered adequate for destroying almost all yeasts, molds, and common spoilage bacteria and also to ensure adequate destruction of common pathogenic, heat-resistant organisms (including *Mycobacterium tuberculosis*, which causes tuberculosis, but not *Coxiella burnetii,* which causes Q fever).[38] As a precaution, modern equipment tests and identifies bacteria in milk being processed. HTST pasteurization processes must be designed so the milk is heated evenly, and no part of the milk is subject to a shorter time or a lower temperature.

Even pasteurization without quality control can be effective, though this is generally not permitted for human consumption; a study of farms feeding calves on pasteurized waste milk using a mixture of pasteurization technologies (none of which were routinely monitored for performance) found the resulting pasteurized milk to meet safety requirements at least 92% of the time.[39]

An effect of the heating of pasteurization is that some vitamin, mineral, and beneficial (or probiotic) bacteria is lost. Soluble calcium and phosphorus levels decrease by 5%, thiamine (vitamin B_1) and vitamin B_{12} (cobalamin) levels by 10%, and vitamin C levels by 20%.[22][40] These losses are not significant nutritionally.[41]

Verification

Direct microbiological techniques are the ultimate measurement of pathogen contamination, but these are costly and time-consuming (24–48 hours), which means that products are able to spoil by the time pasteurization is verified.

As a result of the unsuitability of microbiological techniques, milk pasteurization efficacy is typically monitored by checking for the presence of alkaline phosphatase, which is denatured by pasteurization. B. tuberculosis, the bacterium that requires the highest temperature to be killed of all milk pathogens is killed at ranges of temperature and time similar to those that denature alkaline phosphatase. For this reason, presence of alkaline phosphatase is an ideal indicator of pasteurization efficacy.[42][43]

Phosphatase denaturing was originally monitored using a phenol-phosphate substrate. When hydrolysed by the enzyme these compounds liberate phenols, which were then reacted with dibromoquinonechlorimide to give a colour change, which itself was measured by checking absorption at 610 nm (spectrophotometry). Some of the phenols used were inherently coloured (phenolpthalein, nitrophenol) and were simply assayed unreacted.[35] Spectrophotometric analysis is satisfactory but is of relatively low accuracy because many natural products are coloured. For this reason, modern systems (since 1990) use fluorometry which is able to detect much lower levels of raw milk contamination.[35]

Unpasteurized milk

According to the United States Centers for Disease Control between 1998 and 2011 79% of the dairy related outbreaks were due to raw milk or cheese products.[44] They report 148 outbreaks, 2,384 illnesses (284 requiring hospitalizations) as well as 2 deaths due to raw milk or cheese products during the same time period.[44]

Consumer acceptance

Although pasteurization has been practiced for a long time, some consumers contend that they should have the right to buy and sell unpasteurized milk if they want to.

Some consumers also point out that government-enforced pasteurization law has been used as a tool for large business to shut out competition from smaller producers. See the case of the FDA's shut down of Goodflow Juice in 2008.[45]

Products that are commonly pasteurized

- Beer
- Canned food
- Dairy products
- Eggs
- Milk
- Juices
- Low alcoholic beverages
- Syrups
- Vinegar
- Water
- Wines

See also

- Food irradiation
- Flash pasteurization
- Pascalization
- Homogenization
- Pasteurized eggs
- Solar water disinfection
- Thermoduric bacteria
- Food preservation
- Food storage
- Food microbiology
- Sterilization
- Thermization
- Louis Pasteur

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Further reading

- Raw milk expert testimony dated: April 25, 2008 Case: ORGANIC PASTURES DAIRY COMPANY, LLC, and CLARAVALE FARM, INC., Plaintiffs, vs. No. CU-07-00204 STATE OF CALIFORNIA and A.G. KAWAMURA, SECRETARY OF CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE, Defendants. - Expert Witnesses: Dr. Theodore Beals & Dr. Ronald Hull (https://web.archive.org/web/20120503232553/http://realmilk.com/documents/expert-testimony-0508.pdf)
- Here's an alternate view on the alleged safety of pasteurized vs. natural milk from: Johns Hopkins University: Realmilk.com, Webmaster (12 August 2015). "The Johns Hopkins Raw Milk Study - A Campaign for Real Milk". *A Campaign for Real Milk*.

External links

Wikimedia Commons has media related to ***Pasteurization***.

- Online forum on modern day pasteurization equipment (http://www.pasteurizers.info/)
- Extended Shelf Life (http://www.gea-liquid.com/gealiquid/cmsdoc.nsf/WebDoc/webb8g3k2s)
- Unraveling the mysteries of extended shelf life (http://www.innovatewithdairy.com/SiteCollectionDocuments/Unraveling%20the%20Mysteries%20of%20Shelf%20Lifepdf.pdf)
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