Master Brewers
Food Bites

From the Food Safety Committee

Pasteurization: General Concepts and Concerns

Frances Tietje-Wang, Fermly and Food Safety Committee

September 2024

Pasteurization, although included on many food product labels, is not a commonly understood term and is almost a dirty word in some manufacturing facilities. Pasteurization is a method for achieving microbial stability in food and beverage products by applying enough heat to destroy organisms capable of growth following packaging (9). The name for this process comes from Louis Pasteur, who utilized this method to improve the shelf stability of French beer compared with German imports (4). However, it is important to note that heat treatment was known and used long before Pasteur. For example, heat treatment is known as *hiire* in Japan and was utilized for fermented foods and beverages like soy sauce and sake many centuries before Pasteur applied the same methods to fermented products in Europe (5).

The Basics of Pasteurization

Pasteurization has evolved over the centuries, but its purpose has not. There seems to be some confusion, with some assuming the process is used to achieve sterility. Sterility is to have absolutely no living organism remaining, while pasteurization, as it is used in most industries (e.g., milk and wine), is used to achieve "practical sterility" (3). In brewing, practical sterility through pasteurization is meant to achieve microbial stability using heat to kill off some microorganisms that can grow, but not at temperatures high enough to kill other organisms, such as heat-resistant spore-forming bacteria, that do not grow in beer. It is important to note that pasteurization is not a solution to poor cleaning practices and the impact these can have on beer quality (9).

Calculating Effectiveness

Temperature and the length of time that it is applied are the main factors in pasteurization. A number of concepts have been developed to explain and quantify this process:

- ***D* Value:** The time required for a decimal reduction (one log or 90%) in the population numbers of a known organism at a set temperature. For example, if a particular microorganism has a *D* value of 2 min at 60°C, it means that it takes 2 min at 60°C to reduce the population of that microorganism by 90% (Table 1).
- ***z* Value:** The temperature change required to change the *D* value by a factor of 10. In other words, it is the temperature increase needed to achieve a 10-fold reduction in the time required to kill a specific number of organisms. For example, if a microorganism has a *z* value of 5°C, it means that increasing the temperature by 5°C will reduce the *D* value by a factor of 10. Conversely, decreasing the temperature by 5°C will increase the *D* value by a factor of 10. The *z* value is essential for designing and optimizing pasteurization processes, as it helps determine the relationship between time and temperature required to achieve effective microbial inactivation (Table 1).
- ***P* Value:** The time required to reduce the numbers of a microbial population at a given temperature and *z* value. For the *P* value to have meaning, the temperature and *z* value must be specified so it can be used to provide the time required to produce a specified log reduction in organism numbers. We have simplified this to pasteurization unit (PU) in the brewing industry.
- **Pasteurization Unit:** PU is based on the temperature being 60°C and a *z* value of 6.94°C. One PU = 1 min at 60°C.
- **Lethality Rate (L_T):** The rate at which microorganisms are inactivated or killed during pasteurization, which is dependent on the temperature and duration of the heat treatment and the thermal resistance of the specific microorganisms (9).

Based on these values, equations can be utilized to assist in pasteurization practices.

For L_T, relating the *D* value at 60 to a given temperature (T) and expressed in time in minutes, the equation used is:

$$L_T = D_{60}/D_T$$

To calculate the PU of 1 min at any given temperature (T), the equation used is:

$$\text{PU} = 1.393^{(T-60)}$$

Total PU can be obtained by multiplying the result by the time (t) in minutes at that temperature (T):

$$\text{PU} = t \times 1.393^{(T-60)}$$

Table 1. *D* and *z* values for microorganisms

Organism	D_{60} Value (min)	*z* Value (°C)
Saccharomyces cerevisiae	0.01	4.6
Saccharomyces pastorianus	0.004	4.4
Saccharomyces diastaticus	0.06	7.8
Lactobacillus paracasei	0.02	6.5
Aspergillus niger	0.04	3.7
Pediococcus sp.	0.00073	4.0
Hansenula anomala	0.0039	4.6
Pichia membranaefaciens	0.00025	2.8
Lactobacillus frigidus	0.44	15
Lactobacillus delbrueckii	0.091	12

Ask the Food Safety Team

Ever have a food safety question you don't know the answer to or for which you would like a second opinion? The Food Safety team is there to help! Just post your question in the MBAA Food Safety Community of Practice, and the MBAA Food Safety Committee will weigh in or get another expert's answer for you!

Process of Pasteurization

Once the goal of pasteurization and how to achieve it are understood, this information can be applied to the process.

Step 1: Heat Treatment

With the calculations made, the beer is heated to the specified temperature for a defined period of time to achieve practical sterility. Typical pasteurization temperatures range from 60 to 70°C, depending on the method, style of beverage, packaging, and the microorganisms of concern. It is necessary to precisely control the temperature to avoid any adverse effects, while also considering the importance of uniform temperature control to ensure consistent pasteurization.

Step 2: Cooling

After heating, the product must be cooled. Rapid cooling is necessary to stop the heat treatment and prevent further changes to the beverage's properties beyond the desired microbial stability. The method of cooling used is dependent on the process utilized for heat treatment, which must be efficient and well-controlled to avoid heat damage.

Packaging Considerations

Whether the product is packaged prior to pasteurization or after, several things must be considered regarding the impact of particular conditions on microbial and shelf stability.

- **Sanitary Conditions:** All equipment used in the manufacturing of a product should be kept clean and maintained with regular education, training, and review of cleaning standard operating procedures (SOPs). Maintaining a clean environment, including personal hygiene, is the first and best step to avoid contamination or another problem that may impact the shelf stability of the beverage. Pasteurization processes will not address the root cause of poor cleanliness in a manufacturing environment, only temporarily cover it up, if that (8).
- **Oxygen Control:** Oxygen levels can impact flavor and microbial stability. Pasteurization does not resolve process issues where enough oxygen is in contact with the beverage to eventually result in the oxidation of key flavor compounds. There are microorganisms that thrive on oxygen, so if there is enough of a microbial load in the package that survived pasteurization or came in through an unsanitary practice, there is the possibility that these microbes will thrive. Oxygen levels can be addressed prepackaging by utilizing inert gas purging, deaerated water, and strict process controls and by incorporating oxygen-scavenging materials in bottle caps and can liners (6).
- **Seal/Seam Integrity:** A good seal/seam does double duty: it keeps things out and ideally keeps stable products in. A seal that cannot maintain its integrity will let in oxygen and other contaminants that can accelerate spoilage and possibly create a vector for foodborne illnesses. The seal also is vital in tunnel pasteurization, since heating can agitate the carbon dioxide and any weakness will be exploited by the gas. Bad seals can result in explosions, product damage, and possibly loss of consumer trust. This can be addressed by regularly inspecting seals/seams, as well as investing in quality equipment (1).
- **Convection Currents**: During the pasteurization of a packaged product, convection currents can occur. Convection currents happen when a warmer liquid rises while a cooler liquid descends, creating a circular flow pattern within the container and impacting the uniformity of pasteurization of the beverage. This problem is affected by the container shape and size, viscosity of the beer, and temperature gradients. There are sensors that can be purchased to assess whether a uniform pasteurization temperature is being achieved throughout the package (6).
- **Labeling and Storage:** Labeling is important for quality and traceability. Essential information like batch number, production date, best-before date, and storage instructions are all important. Some of this information matters in tracking the product and managing inventory, but storing pasteurized beer under optimal conditions will also help maintain its quality. Labeling information makes it easy to implement a first-in, first-out practice to ensure that older stock is used first and to maintain freshness.
- **Timing:** Pasteurizers work best when moving at a constant rate. A stop can result in some product being at pasteurization temperatures for an extended period of time, impacting flavor compounds. This is of particular concern with flash pasteurizers, since the product goes directly to packaging operations, which has its own timing situation depending on set-up, SOPs, personnel, etc. (9).

Other Things That Impact Microbial Stability

Pasteurization is a proven process for achieving microbial stability, but it is most effective when it works synergistically with other factors that make a product inhospitable to microorganisms. The more hurdles that are presented to prevent contamination, the less pasteurization is necessary.

- **Alcohol:** Beer usually has a decent ethanol content, generally 3.5–5% by volume. Ethanol inhibits cell membrane functions, increasing permeability and reducing the ability of a cell to maintain homeostasis. Alcohol is heat sensitive, however, which can result in loss of volatile compounds, meriting a decision to go with minimal pasteurization.
- **Hops:** Hops contain isomerized α-acids (IAAs) that specifically impact Gram-positive bacteria cell membrane permeability. However, many beer spoilage bacteria have mechanisms that are resistant to these effects. IAAs are sensitive to heat and are often altered, which impacts the bitterness these compounds are known for and shifts the flavor and aroma profile of the beverage.
- **pH:** A low pH (below 4.2) inhibits the growth of many microorganisms. At low pH, entry of organic acids into the cell increases, causing intracellular acidification that can impact enzyme systems and reduce nutrient uptake. This effect is increased further in high-alcohol or -hop environments, with many pathogenic bacteria unable to grow at lower pH. pH does affect the chemical stability of flavor compounds, so preservation of this aspect during pasteurization should be considered.
- **Carbon Dioxide (CO_2):** Carbon dioxide is a natural by-product of fermentation, creating an anaerobic, low-pH environment that is inhospitable to many microorganisms. An increase in heat also increases the movement of gas molecules, which can cause packaging to burst if the pasteurization process is not undertaken with caution and package integrity is not considered.
- **Low Nutrient Content:** If there are fewer compounds, like sugar, that microorganisms can use as fuel, then growth is significantly limited. Most substrates are utilized during the fermentation process, limiting compounds that can be impacted by heat-induced chemical changes during pasteurization, like the Maillard reaction, and maintaining the flavor profile.

By understanding the impact of each of these factors on the microbial stability of a beverage, breweries can optimize their pasteurization process to preserve the quality and desired characteristics of the beer (9).

Challenges

There are several hurdles that must be addressed when considering incorporation of pasteurization into brewing processes. The biggest issues are cost, sustainability, and organoleptic impact (Fig. 1). These issues are integrated, with cost being one of the main concerns, including capital ex-

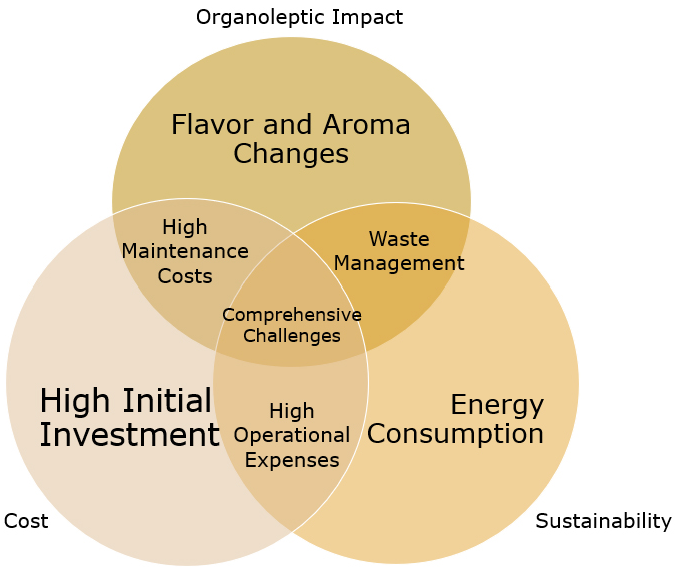

Figure 1. Challenges to pasteurization.

penditures to purchase equipment, operational expenses (energy and water), and ongoing service requirements. Pasteurization has sustainability issues due to energy consumption for heating and cooling, water usage, and dealing with recycling waste and heat by-products. The organoleptic impact is a hot topic regarding pasteurization due to the proven degradation of aromatic compounds, mouthfeel, and perceived freshness.

Conclusions

Pasteurization is an established method for achieving microbial stability in beverage products. In focusing on practical sterility, this practice becomes more accessible for breweries to attain this goal with less impact on organoleptic properties. There are several other concepts to assist in evaluating the appropriate PUs, from logarithmic reduction in the microbial population (*D* value) to the *z* value (temperature to achieve the *D* value), that can be applied while choosing the appropriate method of flash, tunnel, or batch pasteurization. Understanding the beverage and the aspects that can work synergistically in microbial stability, like alcohol content, hops, pH, carbon dioxide, etc., should play a role in choosing whether pasteurization is necessary and what the minimal requirement is. Beyond these considerations, there are still the challenges of cost, sustainability, and organoleptic impact.

There are alternatives to pasteurization, but they are not ideal for all beverages or producers:

- **Sterile Filtration:** The beverage goes through a filter after mainstream filtration and stabilization. The filter has pore sizes smaller than 0.45 µm, which removes microorganisms to ensure microbial stability. This method may be used prior to pasteurization (6).
- **Microbial Control Agent:** This agent penetrates the cell membranes of microorganisms and inactivates enzymes and metabolic processes to achieve microbial stability. It breaks down into nontoxic trace compounds that do not impact flavor (2). Although effective, control agents like dimethyl dicarbonate (Velcorin) require special equipment because of their toxicity.
- **Preservatives:** Sulfur dioxide, potassium metabisulfite, sorbic acid, sodium benzoate, and specific mushroom extracts. Sulfur dioxide and potassium metabisulfite have antioxidant and antimicrobial properties, sorbic acid inhibits yeast and mold growth, and sodium benzoate inhibits these in addition to bacteria. All of these extend the shelf life and stability of beer.
- **Additional Processes:** High-pressure processing, pulsed electric fields, power ultrasound, dense-phase carbon dioxide, ultraviolet radiation, and more options are continuing to be studied for their usefulness in nonthermal technology for microbial stability in beer (7).

These alternatives have similar challenges to pasteurization or the additional concerns that certain distributors or sellers will not sell products using particular microbial stability agents.

Brewing continues to evolve, much like the microbes that make the industry what it is, and so will the processes utilized to prevent these microbes from impacting the final product. In seeking sustainable methods and alternatives, pasteurization and other thermal technologies must evolve or be replaced, but we can learn from the lessons learned over the centuries of use of this important technique in food safety.

Recommended Resources

Pasteurization Deep Dive (Brewers Association)
Brewing Microbiology: Managing Microbes, Ensuring Quality and Valorising Waste (Woodhead Publishing Series in Food Science, Technology and Nutrition)
Handbook of Brewing (Routledge Series in Food Science and Technology)
A Review of Pasteurization Literature for Alcohol and Non-alcohol Beers (Master Brewers *Technical Quarterly*)
Tunnel Pasteurization: A Silver Bullet to Microbes but a Possible Stake to the Heart of Brand Standards (Master Brewers *Technical Quarterly*)
Safety Concerns of NA Beer (Master Brewers *Technical Quarterly*)
Development of a Pasteurization Bioindicator for Nonalcoholic Beers (Master Brewers *Technical Quarterly*)
The Influence of Process Parameters on Beer Foam Stability (Master Brewers *Technical Quarterly*)
Pasteurization: Industrial Practice and Evaluation (Master Brewers *Technical Quarterly*)
Measuring Points and PU Pick-Up (Master Brewers *Technical Quarterly*)

References

1. Briggs, D. E., Brookes, P. A., Stevens, R., and Boulton, C. A. 2004. Brewing: Science and Practice. Woodhead Publishing, Cambridge, England.
2. Costa, A., Barata, A., Malfeito-Ferreira, M., and Loureiro, V. 2008. Evaluation of the inhibitory effect of dimethyl dicarbonate (DMDC) against wine microorganisms. Food Microbiol. 25:422-427. DOI: https://doi.org/10.1016/j.fm.2007.10.003
3. EBC Technology and Engineering Forum. 1995. Beer Pasteurisation: Manual of Good Practice. Getränke-Fachverlag Hans Carl, Nuremberg, Germany.
4. Hornsey, I. S. 2007. A History of Beer and Brewing. Royal Society of Chemistry, London, UK.
5. Lee, V. 2021. The Arts of the Microbial World: Fermentation Science in Twentieth-Century Japan. University of Chicago Press, Chicago, IL.
6. Lewis, M. J., and Bamforth, C. W. 2007. Essays in Brewing Science. Springer, New York, NY.
7. Milani, E. A., and Silva, F. V. M. 2022. Pasteurization of beer by non-thermal technologies. Front. Food Sci. Technol. 1. DOI: https://doi.org/10.3389/frfst.2021.798676
8. Rench, R. J. 2018. Brewery Cleaning: Equipment, Procedures, and Troubleshooting. Master Brewers Association of the Americas, St. Paul, MN.
9. Wray, E. 2015. Reducing microbial spoilage of beer using pasteurisation. Pages 253-269 in: Brewing Microbiology. A. E. Hill, ed. Woodhead Publishing, Sawston, UK. DOI: https://doi.org/10.1016/B978-1-78242-331-7.00012-5