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# Preservatives in Brewing: Science and Regulations

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Beer preservation is essential for maintaining the quality, flavor, and safety of the product through its life cycle from production, through distribution, to consumption. Brewers face the challenge of ensuring that the beer that reaches customers' hands beyond the taproom is in the best possible condition and free from contamination. Preservatives are vital in this process for extending shelf life, inhibiting microbial growth, and maintaining stability.

There are natural preservatives in beer, but compounds can be added to improve shelf stability and address microbial concerns. We will look at how preservatives work, how they align with food safety practices, and what brewers need to consider in this shifting market. Through understanding the science and regulatory aspects of preservatives, informed decisions can be made that can balance product integrity with consumer expectations.

## What Are Preservatives in Beer?

Preservatives are substances that occur naturally in or are added intentionally to beer to extend shelf life and prevent spoilage in different ways (1):

- **Inhibition of Microbial Growth**
  A primary function of preservatives is to prevent the microbial growth of yeasts, bacteria, and molds. These microorganisms can quickly degrade the quality of beer, leading to off-flavors, at least, and health risks, at most. Microbial growth is addressed by preservatives in several ways:
  - Disruption of cell membranes
  - Inhibition of enzyme activity
  - Acidification and pH alteration
  - Inhibition of protein synthesis
  - Disruption of genetic material
  - Dehydration via osmotic pressure
  - Inhibition of growth
- **Prevention of Oxidation**
  Oxidation is a major factor in product aging over time, resulting in stale, "cardboard-like," or "papery" off-flavors. Preservatives with antioxidant properties neutralize free radicals that would otherwise cause oxidative reactions, leading to undesirable flavors. Although some beer styles are more stalwart due to certain natural compounds in the process, adding other antioxidants can help prolong beer freshness, particularly during storage and distribution. Proper packaging and careful handling of beer during production are excellent ways to minimize oxygen exposure, but preservatives can offer an extra layer of protection to maintain the intended flavor profile.
- **Retention of Aroma and Color Integrity**
  Over time, color and aroma can be degraded as oxidation and microbial growth cause certain chemical reactions. Both can cause color shifts that dull beer clarity or develop undesirable hues. Hop aromas, especially in dry-hopped beers, are especially vulnerable to oxidation and can be lost. In inhibiting the presence of microbes and particular chemical reactions, preservatives help ensure the product is distributed and consumed as intended.

## Commonly Used Preservatives in Beer

A variety of natural and chemical or artificial additives and preservatives are used in beer (2):

- **Natural Preservatives**
  Substances that occur naturally during the brewing process or are naturally occurring:
  - **Hops:** Provide weak acids that create an environment hostile to many spoilage bacteria by disrupting their cellular processes (3).
    - **Iso-α-acids:** Formed during the boiling process when hops are added. They inhibit the growth of spoilage organisms by disrupting the cell membrane, leading to cell death.
    - **Humulones:** Although not as formidable as iso-α-acids, humulones help maintain beer stability by preventing microbial contamination.
  - **Alcohol:** Ethanol is produced by yeast as a natural product of fermentation. It disrupts the integrity of microbial cell membranes, causing leakage of cellular contents and leading to cell death. It also inhibits unwanted fermentation by other yeasts and bacteria that could cause spoilage.
  - **Acids:** There are naturally occurring acids in beer provided by hops, but there can be an additional presence via lactic acid (produced by lactic acid-producing bacteria) and acetic acid (produced in some sour beers). Acids act as preservatives by lowering the pH of the product. Most harmful bacteria prefer neutral to slightly acidic conditions (pH 6–7). Organic acids dissociate in water, releasing hydrogen ions and lowering the pH.

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- **Chemical and Artificial Additives and Preservatives**
  Chemical and artificial substances can intentionally be added to beer to extend its shelf life, prevent microbial growth, and maintain product quality. However, some of these substances can cause allergic reactions in people or require extensive safety considerations and investment before utilizing.
  - **Ascorbic Acid (Vitamin C):** A natural preservative that can be added to beer to prevent oxidation, ascorbic acid neutralizes free radicals and reactive oxygen species. These highly reactive compounds can damage aromatic compounds, impacting aroma and phenolic compounds and affecting color (4).
  - **Chitosan Fibers:** Extracted from the stems of white button mushrooms (*Agaricus bisporus*), this natural preservative can be used to enhance the quality and shelf-life of various products, including beer. Chitosan molecules have cationic (positive charge) properties that allow them to interact with the negatively charged cell membranes, disrupting their integrity. This is effective against a broad spectrum of microorganisms. The fibers also can form a protective barrier on the surface of a product, preventing access to nutrients and oxygen, as well as further contamination. The fibers also scavenge free radicals, acting as an antioxidant and preventing the effects of oxidation (5).
  - **Sodium Benzoate:** This preservative dissociates into benzoic acid in acidic environments (pH 4–5), at which point it can penetrate cell walls and interfere with enzyme activities, particularly those involved in energy production (6).
  - **Potassium Sorbate:** A fungistatic agent, this preservative interferes with the biosynthesis of sterols in the cell membranes of yeasts and molds. It also disrupts the mitochondrial function, preventing the ability of these microbes to reproduce and is effective in stopping fermentation.
  - **Sulfites:** Sulfur dioxide ($SO_2$) and sodium bisulfite ($NaHSO_3$) act as strong reducing agents. They scavenge oxygen and react with free radicals, preventing oxidation and its impact on flavor and color. Sulfites also can act as microbial agents, disrupting the cell wall and interfering with cellular respiration (7).
  - **Dimethyl Dicarbonate (DMDC):** A chemical sterilizer that disrupts microbial DNA, DMDC causes irreversible damage to the reproductive ability of microbes. It reacts with nucleophilic groups in microbial DNA, leading to alkylation of the DNA and proteins and effectively sterilizing the product without affecting beer flavor or quality. Methanol and carbon dioxide are by-products of the process. Methanol, in particular, can be toxic and impact the flavor and aroma of beer (8).

## Regulatory Considerations

Use of preservatives must follow the U.S. Food and Drug Administration (FDA) and Alcohol and Tobacco Tax and Trade Bureau (TTB) regulations to ensure consumer safety, proper labeling, and product integrity (9).

- **A Brief Overview of FDA Guidelines for Preservatives:** The FDA regulates the use of preservatives in foods and beverages through the Food, Drug, and Cosmetic Act. The use of preservatives must comply with safety standards and regulations:
  - **Generally Recognized as Safe (GRAS):** Some preservatives, like those naturally occurring in beer (e.g., alcohol, hops), and organic acids, are considered GRAS by the FDA, which means they do not require premarket approval before use.
  - **Approval for Chemical Preservatives:** For other artificial preservatives, manufacturers must ensure they comply with the FDA's Food Additive Regulations. These chemicals can only be used within specific concentrations established by the FDA based on safety testing.
- **Labeling Requirements:** The FDA has specific requirements for labeling when preservatives are used, especially if they are chemical (10,11):
  - **Ingredient Declaration:** Any preservatives must be listed on the product label, especially with chemical preservatives, in accordance with the Federal Food, Drug, and Cosmetic Act (12).
  - **Consumer Awareness:** Labels must also inform consumers if the beer contains preservatives, like sulfites, that may trigger allergic reactions or sensitivities.
- **Standards of Identity for Beer:** The FDA and TTB cooperate on standards of identity for beer, which are regulations that define what constitutes a "beer" in the United States. These standards outline ingredients, processes, and quality expectations for different beer styles(13):
  - **Beer Composition:** FDA standards ensure that any additives used do not interfere with the identity of beer, like altering the color, flavor, aroma, etc. Excessive use of preservatives may cause an off-flavor or alter the beer to the point that it no longer meets the defined style.
  - **Alcohol Content and Ingredients:** Preservatives must comply with TTB regulations concerning alcohol content and ingredients used in the brewing process, which should not conflict with these standards.

## Food Safety and Quality Considerations

Preservatives are essential for ensuring beer safety and extending shelf life, but their impact on taste and consumer perception should not be dismissed.

- **Impact of Preservatives on Beer Taste and Quality:** Natural preservatives like hops and alcohol contribute to a beer's flavor, adding enjoyable bitterness and depth. The addition of chemical preservatives, like sodium benzoate and potassium sorbate, however, can impart off-flavors or alter a beer's flavor (14).
- **Balancing Preservation and Flavor:** Natural preservatives and chemical preservatives need to be carefully balanced, with the latter minimized to preserve the beer's authenticity and meet consumer flavor preferences.
- **Consumer Preferences and Product Perception:** Demand for natural and minimally processed foods and beverages is rising, indicating the increasing importance of consumer-friendly preservation methods in the beverage industry. The perception that preservatives in alcoholic beverages cause headaches and bad hangovers has led to a growing market in preservative-free versions; therefore, consideration of the additives used and their influence on product perception and market influence is necessary.

## Best Practices for Brewers

A brief list of best practices for quality and consistency in brewing production includes (15)

- **Proper Sanitation:** Rigorous sanitation is essential to prevent microbial contamination, reducing the need for preservatives. Using Good Manufacturing Practices (GMPs) ensures that all equipment and surfaces are thoroughly cleaned and sanitized, minimizing spoilage risks. Regular monitoring with plating and

ATP testing can verify the effectiveness of sanitation protocols (16).

- **Monitoring Shelf Life:** Regular testing for microbial contamination is essential for ensuring beer quality throughout its shelf life. This includes microbial analyses and sensory evaluation to assess flavor stability.
- **Alternative Methods of Preservation**
  - **Cold Storage:** Storing beer at low temperatures slows microbial growth and oxidation, preserving flavor and quality. Maintaining the cold chain is vital when a beer is distributed beyond the taproom.
  - **Pasteurization:** Heat-treating beer can kill spoilage organisms and extend the shelf life, but it can impact the flavor profile, so it must be balanced between preservation and taste (17).
  - **Filtration:** Removing yeast and other particulates can reduce microbial load and improve clarity and stability (18).
  - **Carbon Dioxide:** Proper carbonation during packaging and storage prevents oxidation and spoilage.

## Conclusions

Preservation plays a pivotal role in maintaining the safety, flavor, and stability of beer but presents a challenge for brewers in safeguarding against microbial contamination, oxidation, and degradation of the product. While natural preservatives like alcohol, hops, and organic acids help maintain freshness and prevent spoilage, additional preservatives can be used to extend shelf life and improve stability. Both kinds of preservatives must be balanced, considering needs and drawbacks. The growing demand for preservative-free or minimally processed beverages highlights the importance of food safety and consumer preferences when selecting a method and substance. Starting with best practices, like proper sanitation, and monitoring shelf life, and exploring alternative preservation methods, like cold storage, pasteurization, filtration, and carbon dioxide, can help brewers meet quality and safety standards. Ultimately, understanding the science behind preservatives, GMPs, and the regulatory landscape empowers brewers to make the best choices for the quality of their business as market expectations evolve.

## Quick tips

- Stay informed on regulations and best practices for using preservatives in beer.
- Use quality control and testing to ensure the right balance of preservation without compromising flavor.

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