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The role of microbes in cream quality and safety: A comprehensive overview

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Abstract
Cream, a fat-rich dairy product, is inherently susceptible to microbial contamination and subsequent spoilage due to its nutrient-rich composition and water activity. This abstract summarizes the diverse microbial ecology of cream, tracing the primary sources of contamination from raw milk, processing environments, and handling practices. Key microbial groups, including psychrotrophic bacteria (e.g., *Pseudomonas*), mesophilic bacteria (including lactic acid bacteria), coliforms, spore-formers (*Bacillus*, *Clostridium*), and potential pathogens (*Staphylococcus aureus*, *Salmonella*, *Listeria monocytogenes*), are highlighted alongside their roles in various spoilage mechanisms such as souring, rancidity, bitterness, and textural defects. The critical role of pasteurization in ensuring safety and extending shelf life is discussed, contrasting different heat treatment methods (LTLT, HTST, UP, UHT). Finally, essential strategies for microbiological control throughout the production chain, encompassing raw milk quality, hygienic processing, effective pasteurization, prevention of post-processing contamination, and proper storage, are emphasized as crucial for delivering safe and high-quality cream to consumers. Understanding and managing the microbial landscape of cream is paramount for the dairy industry to mitigate spoilage and safeguard public health.

Keywords: Rancidity, souring, lipolysis, proteolysis, quality control, hygiene

Introduction
Cream, the lipid-rich emulsion skimmed from milk, stands as a significant dairy commodity valued for its texture, flavor, and versatility in culinary applications. However, its rich nutrient composition and relatively high-water activity make it a susceptible substrate for microbial proliferation, impacting both its quality and safety. Understanding the intricate microbial ecology of cream, from its origins in raw milk to the influences of processing and storage, is paramount for ensuring a safe and palatable product for consumers. This article delves into the diverse microbial populations associated with cream, the sources of contamination, the mechanisms of spoilage, the critical role of pasteurization, and the strategies employed to maintain its microbiological integrity.

Sources of Microbial Contamination in Cream
The microbial inhabitants of cream are not inherent but rather introduced at various stages of its journey from the cow to the consumer. Identifying these sources is the first step in controlling microbial loads.

1. Raw Milk as the Primary Source
The initial microbial flora of cream is intrinsically linked to that of the raw milk from which it is derived. This native microbiota is a complex consortium of bacteria, and occasionally yeasts and molds, originating from:

- **The Udder:** Even under healthy conditions, the bovine udder is not sterile and harbors a resident microflora, including lactic acid bacteria (LAB) such as *Streptococcus* and *Lactococcus* species, as well as non-lactic streptococci and corynebacteria [1]. Subclinical mastitis can significantly elevate the microbial load and introduce opportunistic pathogens.
- **The Teat Surface:** The exterior of the teat is exposed to the farm environment and can be a source of environmental contaminants, including coliforms, spore-forming bacteria like *Bacillus* and *Clostridium*, and Gram-negative psychrotrophs [2].
- **Milking Equipment:** Improperly cleaned and sanitized milking equipment can serve as a significant reservoir for microbial contamination, contributing bacteria such as *Pseudomonas*, *Alcaligenes*, and *Acinetobacter* [3].

2. Contamination During Processing
The journey from raw milk to finished cream involves several processing steps that can introduce or exacerbate microbial contamination:

- **Separation:** While the separation process itself is generally a closed system, inadequate cleaning and sanitation of the separator can lead to the transfer of biofilms and residual microorganisms into the cream [4].
- **Handling and Transfer:** Open handling and transfer steps increase the risk of airborne contamination and contact with surfaces harboring microorganisms.
- **Packaging:** Contaminated packaging materials or inadequate filling and sealing processes can introduce spoilage organisms and pathogens [5].
- **Water Quality:** Water used for rinsing equipment or in processing must be of potable quality to avoid contamination with waterborne pathogens and spoilage bacteria.

3. Human Handling
Dairy personnel can inadvertently introduce microorganisms, including potential pathogens like *Staphylococcus aureus* and *Salmonella* species, through direct contact if proper hygiene practices are not strictly adhered to [6].

4. Environmental Sources

The processing environment, including air, dust, and surfaces, can harbor a diverse microbial population that can contaminate cream, particularly if processing areas are not adequately cleaned and maintained [7].

Dominant Microbial Groups in Cream

The microbial community in cream is dynamic and influenced by factors such as the initial raw milk microflora, processing conditions, and storage temperature.

1. Bacteria

- **Psychrotrophic Bacteria:** These cold-tolerant microorganisms are of particular significance in refrigerated cream, as they can proliferate even at low temperatures and are major contributors to spoilage. Key psychrotrophic genera include *Pseudomonas* (e.g., *P. fluorescens*, *P. fragi*), *Alcaligenes*, *Acinetobacter*, *Aeromonas*, and *Achromobacter* [8]. Their metabolic activities result in lipolysis, proteolysis, and the production of various off-flavors and odors.

- **Mesophilic Bacteria:** These organisms thrive at moderate temperatures and include lactic acid bacteria (LAB) such as *Lactococcus*, *Streptococcus*, and *Lactobacillus*, as well as other genera like *Corynebacterium*, *Bacillus*, *Micrococcus*, and *Staphylococcus* [9]. While some LAB contributes to desirable fermentation in other dairy products, their growth in cream can lead to souring.

- **Lactic Acid Bacteria (LAB):** As mentioned, various genera of LAB can be present in cream. While some may originate from the raw milk, others can be contaminants. Their primary metabolic activity is the fermentation of lactose to lactic acid, resulting in a decrease in pH and a sour taste [10].

- **Coliform Bacteria:** The presence of coliforms, particularly *Escherichia coli*, is often indicative of fecal contamination and poor hygiene practices. While many coliforms are not pathogenic, their presence signals a potential risk of other enteric pathogens [11].

- **Spore-Forming Bacteria:** Genera like *Bacillus* and *Clostridium* are resilient due to their ability to form spores that can survive pasteurization. Post-pasteurization contamination with spore-formers can lead to spoilage defects such as sweet curdling (due to heat-stable proteolytic enzymes from *Bacillus cereus*) and gas production [12].

- **Pathogenic Bacteria:** Although their presence is undesirable and should be minimized through proper practices, cream can be contaminated with pathogens such as *Staphylococcus aureus* (producing heat-stable toxins), *Salmonella* species, and *Listeria monocytogenes*, posing a significant food safety risk [13]. *Enterococcus faecalis* and *Enterococcus faecium* are also found and can indicate fecal contamination.

2. Yeasts and Molds

Compared to bacteria, yeasts and molds are generally less prevalent in properly handled and refrigerated cream. However, they can grow on the surface, particularly under aerobic conditions and at lower temperatures, leading to visible spoilage and the development of taints and off-flavors. Common genera include *Candida*, *Geotrichum* (*dairy mold*), and various filamentous molds [14].

Spoilage Mechanisms in Cream

Microbial activity in cream leads to a variety of spoilage defects, rendering the product unacceptable to consumers.

- **Souring:** The fermentation of lactose by lactic acid bacteria results in the production of lactic acid, leading to a decrease in pH and a characteristic sour taste and odor [15].

- **Rancidity:** Lipolytic enzymes produced by psychrotrophic bacteria, particularly *Pseudomonas* and the mold *Geotrichum candidum*, hydrolyze milk fat (triglycerides) into free fatty acids. Short-chain fatty acids, such as butyric and caproic acid, have pungent and unpleasant odors and flavors [16].

- **Bitterness:** Proteolytic enzymes secreted by certain bacteria, including *Pseudomonas* and *Bacillus* species, break down milk proteins into bitter-tasting peptides [17].

- **Fruity Flavors:** Some *Pseudomonas* species, notably *P. fragi*, can produce volatile compounds that impart fruity or ester-like off-flavors [18].

- **Cheesy or Putrid Flavors:** The breakdown of proteins by proteolytic bacteria like *P. putrefaciens* can result in cheesy, putrid, or ammonia-like odors [19].

- **Slime Formation:** The production of extracellular polysaccharides by certain microorganisms, such as coliforms and some lactococci, can lead to the development of a slimy texture on the surface of the cream [20].

- **Sweet Curdling:** Heat-stable enzymes (lipases and proteases) produced by spore-forming bacteria like *Bacillus cereus* can survive pasteurization and cause coagulation of the cream during storage, even without significant acid production [21].

- **Gas Formation:** The fermentation of lactose or other substrates by certain yeasts or heterofermentative bacteria can lead to the production of gas, resulting in bulging of the packaging [22].

- **Discoloration:** While less common, some microorganisms, such as *Pseudomonas nigrificans*, can produce pigments that cause discoloration of the cream [23].

Pasteurization: A Critical Control Point

Pasteurization is a heat treatment process designed to eliminate pathogenic microorganisms and significantly reduce the number of spoilage organisms in cream, thereby ensuring its safety and extending its shelf life. The specific time-temperature combinations employed are carefully chosen to achieve these goals without causing significant damage to the quality attributes of the cream.

Common pasteurization methods for cream include:

- **Vat Pasteurization (Low-Temperature Long-Time - LTLT):** Heating the cream to 63°C (145°F) for 30 minutes [24].
- **High-Temperature Short-Time (HTST):** Heating the cream to 72°C (161°F) for 15 seconds. Higher temperatures, such as 89°C to 100°C for shorter durations, are also utilized depending on the fat content and desired shelf life [25].
- **Ultra-Pasteurization (UP):** Heating the cream to at least 138°C (280°F) for a minimum of 2 seconds. This process significantly reduces the microbial load and extends the refrigerated shelf life compared to conventional pasteurization [26].
- **Ultra-High Temperature (UHT):** Heating the cream to 138-150°C (280-302°F) for 1-2 seconds, followed by aseptic packaging in sterile containers. UHT-treated cream is commercially sterile and can be stored at ambient temperatures until opened [27].

The higher fat content of cream can offer some protection to microorganisms against heat treatment. Therefore, pasteurization parameters for cream may be adjusted accordingly to ensure effective microbial inactivation [28].

Factors Influencing Microbial Growth in Cream

Several intrinsic and extrinsic factors influence the growth and activity of microorganisms in cream:

- **Temperature:** Temperature is a critical factor. Psychrotrophs thrive at refrigeration temperatures, while mesophiles dominate at ambient temperatures. Proper refrigeration is essential to inhibit the growth of spoilage and pathogenic microorganisms [29].
- **Nutrient Availability:** Cream is a rich source of fats, proteins, and lactose, providing ample nutrients to support microbial growth [30].
- **Water Activity:** The water activity of cream, while relatively high, is slightly lower than that of milk due to the higher fat content. However, it is still sufficient to support the growth of many bacteria, yeasts, and molds [31].
- **pH:** Fresh cream typically has a pH ranging from 6.4 to 6.8, which is within the optimal range for the growth of many spoilage and pathogenic bacteria. Souring by LAB will decrease the pH, potentially inhibiting the growth of some other microorganisms but rendering the product unacceptable [32, 33].
- **Oxygen Availability:** Aerobic and facultative anaerobic bacteria, yeasts, and molds can grow in cream exposed to air. Proper packaging that minimizes oxygen exposure can help to extend shelf life by inhibiting aerobic spoilage organisms [34].
- **Redox Potential (Eh):** The redox potential influences the types of microorganisms that can grow. Aerobic conditions favor the growth of aerobes, while anaerobic conditions favor anaerobes.
- **Storage Time:** The duration of storage directly impacts the extent of microbial proliferation and the potential for spoilage. Longer storage times allow for the accumulation of microbial metabolites and an increased risk of quality defects [35].

Strategies for Microbiological Control in Cream Production

Maintaining the microbiological quality and safety of cream requires a multi-faceted approach encompassing the entire production chain.

- **High-Quality Raw Milk:** Starting with raw milk that has a low initial microbial load is crucial. Implementing good animal husbandry practices, proper milking techniques, and efficient cooling of raw milk are essential [36].
- **Hygienic Processing Practices:** Strict adherence to Good Manufacturing Practices (GMPs) and Sanitation Standard Operating Procedures (SSOPs) in the dairy processing plant is paramount. This includes thorough cleaning and disinfection of all equipment and surfaces that come into contact with the cream [37].
- **Effective Pasteurization:** Implementing validated pasteurization processes that are appropriate for the type of cream being produced is critical for eliminating pathogens and reducing spoilage organisms [38].
- **Prevention of Post-Pasteurization Contamination:** Minimizing handling after pasteurization and utilizing sterile or sanitized equipment and packaging materials are essential to prevent recontamination [39].
- **Proper Cooling and Storage:** Maintaining cream at refrigerated temperatures (ideally below 5°C) throughout the distribution chain is vital to inhibit the growth of psychrotrophic spoilage bacteria and prevent the proliferation of any surviving or contaminating microorganisms [40].
- **Aseptic Packaging (for UHT Cream):** For UHT-treated cream, aseptic packaging in sterile containers under sterile conditions is essential to maintain commercial sterility and allow for ambient temperature storage [41].
- **Quality Control and Monitoring:** Implementing robust quality control measures, including regular microbiological testing of raw milk, in-process samples, and finished products, is necessary to monitor the effectiveness of control measures and ensure product safety and quality [42]. This includes testing for total bacterial counts, coliforms, psychrotrophs, and specific pathogens as needed.
- **Employee Training:** Educating dairy personnel on proper hygiene practices, sanitation procedures, and the importance of preventing contamination is a fundamental aspect of microbiological control [43].

Conclusion

The microbiology of cream is a complex interplay of initial contamination, processing influences, and storage

conditions. A diverse array of microorganisms, including bacteria, yeasts, and molds, can inhabit cream and contribute to spoilage, impacting its sensory attributes and potentially posing food safety risks. Pasteurization remains a cornerstone in ensuring the safety and extending the shelf life of cream. However, stringent hygienic practices throughout the production chain, proper temperature control during storage and distribution, and robust quality control measures are equally essential to deliver high-quality and safe cream to consumers. A comprehensive understanding of the microbial landscape of cream is therefore fundamental for the dairy industry to implement effective strategies for microbiological control and ensure product excellence.

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