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A Review on Troubleshooting Effective Factors in Raw Milk Off-Flavor Production: Its Control, Reduction, and Elimination Methods

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ABSTRACT

Milk, a vital product derived from mammalian mammary glands, is essential for newborn nourishment and is widely consumed as a food source. However, various internal and external factors can negatively impact milk's quality, particularly its odor and flavor, which can limit its marketability and cause significant economic losses for farmers. The olfactory sense, being much more sensitive than the sense of taste, plays a key role in the perception of milk's freshness. This review aims to evaluate the factors contributing to off-flavors and odors in raw milk and the methods for controlling, reducing, and eliminating these undesirable characteristics. Examining published literature, preventive strategies and treatment options are explored, including heating, vapor treatment, Vitamin E supplementation, food additives, and flavoring agents. Also, proper nutrition management, mastitis, and other influencing factors are discussed as effective ways to prevent off-flavors. By addressing these challenges, the economic situation of farmers can be improved, leading to enhanced milk quality, greater consumer acceptance, and increased profitability in the dairy sector.

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INTRODUCTION

Milk is a product produced by the mammary glands of mammals for feeding their newborns. It has a unique composition containing various proteins, fats, carbohydrates, vitamins, minerals, and other substances that fulfill the nutritional requirements of newborn animals and humans (Zia, 2016). Due to its high nutritional value and rich nutrient content, milk is often called "white blood" (Irina, 2019). According to FAO reports, global milk production in 2020 was 906 million tons (M.T.), which showed a slight increase in 2021, reaching 937.3 M.T. Milk production, measured by continent, is highest in Asia, followed by Europe, North America, South America, South Africa, and Africa, respectively (FAO, 2021).

Milk production in Asia in 2022 showed a slight increase compared to 2020, reaching 2,421 million tons (M.T.), which accounts for 45% of the world's total milk yield. Among Asian countries, India, China, Pakistan, Uzbekistan, Kazakhstan, and Bangladesh were the leading producers of milk (FAO, 2021; FAO, 2023).

Globally, cows are the primary source of milk for human consumption, contributing approximately 83% of total milk production (Zia, 2016). In Afghanistan, milk production has gradually increased in recent years. According to the 2020 animal census report by the Ministry of Agriculture, Irrigation, and Livestock (MAIL), an estimated 1.35 million families owned 2.1 million milking cows in 2016. These cows produced 1.936 M.T. of milk, accounting for 85% of the country's total milk production. Meanwhile, Afghanistan imported 62.72 million kilograms of dairy products from countries including Pakistan, Iran, Ireland, Uzbekistan, and India to meet domestic demand.

Currently, 30 registered private factories are processing raw milk in Afghanistan, with a maximum production capacity of 160.5 M.T. per day. However, the current daily milk production is approximately 57.3 M.T. Additionally, 753 commercial milk production farms operate across the country (MAIL, 2020).

Various factors influence the composition, quality, and quantity of milk production. These include animal species, breed (hybrids), individual variations, season of the year, age, milking interval, exercise, hormonal influences (e.g., somatotropin), physiological condition, nutrition, pasture quality, environmental temperature, and milking time. By optimizing these factors, favorable milk production can be achieved (Noori et al., 2004; Griffiths, 2020; Zia, 2016). Conversely, external factors such as air temperature, humidity, sunshine, wind, and heat stress can negatively impact milk production (Jawhar et al., 2024; Sesay, 2023).

This study aims to evaluate the various factors influencing off-odors and flavors in milk. It seeks to identify the causes of these issues and provide practical solutions to improve milk quality, offering valuable information to stakeholders in the dairy industry.

RESULTS

Reasons for Non-Selling Fresh Milk

Consumers prefer fresh, natural, and safe milk with proper odor and taste. However, unprocessed raw milk and, at times, even processed milk can develop defects such as off-odors or off-flavors, making them less desirable to consumers. This can result in significant economic losses for milk handlers and sellers (Mohammad, 2007; Gursoy, 2020).

The olfactory system is far more sensitive and complex than the sense of taste. There are thousands of distinct smells in nature, with olfactory sensitivity being 10,000 times greater than taste perception. Various factors influence odors and their perception (Qanbar, 2003).

The sources of odor and flavor in milk are generally categorized into internal and external factors (Su Xueqian et al., 2020). Some studies refer to them as primary and secondary factors (Cadwallader, 2009). Roberts (1993) further classified the sources of off-odors and flavors into three categories, designated as A, B, and C:

1. **A: Absorbance** – Odors absorbed from external sources, such as feed, garlic, onion, and other dietary components.

2. **B: Bacterial Activity** – Odors caused by bacterial processes, such as acid production and fat rancidity.
3. **C: Chemical Reactions** – Odors arising from chemical reactions, such as the production of ketones and other compounds.

This classification provides a systematic approach to identifying and addressing the factors contributing to off-odors and off-flavors in milk, ultimately improving product quality.

Milk Off-Flavor Causes

As briefly stated above about the source and reasons for milk off-flavor, the present section describes factors causing the two mentioned defects. Schiano et al. (2017) reviewed a survey of academic research articles published in the last 100 years regarding milk issues. Finally, they expressed their findings/results as the following factors: acid production, spicy materials, cow odor, stable smell, bitterness, excessive boiling, nutrition, fermentation, fruity smell, tastelessness, chemical materials, garlic, onion, leek, oat smell, light and metal oxidation, rancidity, saltiness, and uncleanness.

Researchers classified the reasons for milk defects, and the mentioned items are placed under one of these titles, such as transmitted flavors or milk absorbing smells during storage. Defects created by light, light-induced defects, and exposure to sunlight cause oxidation, activating riboflavin and hydrolyzing methionine, which results in methanol production.

The taste originating from fat lipolysis leads to a rancid flavor. Microbial flavor defects caused by psychrophilic bacteria spoil the milk. Various bacteria contribute to bad smell production. *Lactobacillus lactis* plays a role in acid production, while psychrophilic bacteria cause a bitter taste in the products. Fat is oxidized by copper and other metals, altering the flavor. Phospholipids and unsaturated fats are more sensitive to oxidation, leading to the formation of aldehydes and ketones. A deficiency of Vitamin C and selenium also causes auto-oxidation.

Higher heating or heat-induced flavor changes the taste and composition of milk ingredients. The Maillard reaction compresses the free amino groups, casein, and lysine, making lactose form a Schiff base that turns brown. This process results in caramel flavor. Adding water to milk changes its taste to flat.

Foreign or external factors such as the smell of paint, oil, kerosene, drugs, etc., either directly or indirectly through absorption, could change milk odor. Furthermore, a salty taste comes from mastitis. Storage in a fridge could provide an opportunity for microorganisms to grow, making the milk appear unclean and, in some cases, even produce a bitter flavor. Packing materials used to prepare containers influence milk taste (Tamime, 2009). Similarly, metallic taste originates from nutrition/feed during lactation, storage, or keeping milk in a stable, as well as fish odor and unfavorable oil transportation.

The appearance of a blue color comes from adding water to the milk. Mastitis produces a pink color; squeezing the udder teat allows blood to enter the milk, changing its color. Adding cheese whey to milk causes a greenish appearance (Irina, 2019).

Millard Reaction

An extremely significant type of chemical degradation in dairy products is the Maillard reaction. In most cases, heat processing such as pasteurization and storage at mild to high temperatures causes non-enzymatic browning. A carbonyl group from a reducing sugar and an amino group from a protein, peptide, or amino acid are needed for the reaction.

In particular, the reaction requires the condensation of carbonyl and amino groups to generate unstable glycosylamine, which is then rearranged to form the Amadori molecule. After going through a number of reaction pathways, such as fission, dehydration, and condensation, the Amadori molecule produces both desirable and undesirable tastes. In dairy products involved in the Maillard process, lactose typically serves as the main reducing sugar (Su, 2020).

Milk Composition on Milk Sensory Quality

Throughout history, bovine milk has been praised for its nutritional value, particularly for the adolescent population. The macronutrient and mineral composition of milk is not the only factor that influences its sensory character. A number of components contribute to the sensory quality of milk by the time it reaches supermarket shelves, including feed, pasteurization methods, vitamin fortification, and packaging. Each of these elements can impact the flavor of fluid milk (Schiano, 2017).

Farm Management

Most people agree that farms are the starting point for producing high-quality dairy products. The ruminants' genetic and physiological traits, as well as the milking techniques, milk storage and collection methods, hygienic conditions of the milking equipment, the farm employees, and the overall management of the farm, all influence the quality of the milk (Manfredini & Massari, 1989; Coulon et al., 2004). Additionally, the farmer's feeding strategies and diets have been demonstrated to affect the milk's sensory quality (Morand-Fehr et al., 2007; Butler et al., 2011; Zervas & Tsiplakou, 2011). Specifically, the season, diet, cooling and milking methods, and barn environment significantly impact the flavor of small ruminant milk (Wolf, 2013).

Macronutrients

The proportions of milk macronutrient components significantly influence how the senses perceive fluid milk. The sensory perception of fluid milk is greatly affected by milk fat. Consumer preferences for milk fat vary, as it is associated with creaminess, which is positively perceived in dairy products. However, despite their preference for whole milk, many consumers purchase reduced-fat milk for health-related reasons. Since January 2005, 2% reduced-fat milk has outsold whole milk every month (Schiano, 2017).

Fortification

Fortification is incorporating micronutrients, such as essential vitamins, into food. When milk accounted for 10% of the food energy consumed by Americans in the 1930s and 1940s, fluid milk fortification was introduced (Yeh et al., 2017b). Following the American Medical Association's Council on Foods and Nutrition recommendation to fortify foods with vitamin D to prevent childhood rickets, this practice became widespread (Stevenson, 1955).

Due to the widespread use of vitamin D-enriched milk, fat-free and reduced-fat milks were also fortified with vitamin A. Today, fortifying reduced-fat milks with vitamins A and D is mandatory to replenish the fat-soluble vitamins lost during skimming. Whole milk fortification with vitamin D is common but optional (PHS/FDA, 2015).

The sensory effects of vitamin fortification in fluid milk have not been extensively studied. According to Hanson and Metzger (2010), the sensory qualities of low-fat strawberry yogurt, high-temperature short-time (HTST) processed 2% unflavored milk, and ultra-high temperature (UHT) processed 2% chocolate milk were unaffected by vitamin D fortification of 100 to 250 IU (international units) per serving. However, other research has revealed that vitamin A fortification may be responsible for unpleasant aromas, such as hay-like or greasy overtones (Whited et al., 2002). Yeh et al. (2017a) recently found that consumers could distinguish between unfortified and fortified milks when skim milk was fortified with vitamin A concentrates at amounts close to the highest limits permitted by law (3,000 IU/quart or 1.65 mg/946 mL).

Processing of Raw Milk

Fluid milk undergoes several processing stages to guarantee consumer safety and consistent quality before consumption. The flavor of fluid milk can be significantly impacted by contact with any surface during processing. However, the following processes are crucial for fluid milk processing: pasteurization, homogenization, packaging, milk fat separation, and fat content standardization (Goff and Griffiths, 2006).

The term "pasteurization," which honors French microbiologist Louis Pasteur, refers to heating food or drink items to destroy microorganisms that could otherwise compromise their safety or shelf life. Government regulations requiring the pasteurization of the U.S. milk supply were introduced in the early 1900s. As a result, the flavor profile of fluid milk has been heavily influenced by this process (Wolf, 2013).

Environmental Conditions

Research on the factors that influence flavor variations in goat milk has revealed that improper management of milk diminishes its authentic flavor (Skjevdal, 1979). Volatile chemicals can directly pass from the surrounding environment to the milk in atmospheres where silage or animal scents predominate. Off-flavors in milk can be transferred or absorbed before, during, and after milking.

The "goaty" flavor in fresh goat milk is sometimes attributed to the stench of male goats in rut. Due to the high volatility of buck odors, it is advised that bucks be isolated from the milking area. A major contributor to this odor has been identified as 6-trans-nonenal, which is produced by the sebaceous glands on the scalps of sexually active bucks, either as a pheromone or as a byproduct of oxidation of certain precursors in the gland lipids (Smith et al., 1984).

Types Of Milk: Powdered, Fresh, Sterilized, Condensed

Dry milk, or milk powder, has long been regarded as a significant thermally treated milk product. According to Lloyd et al. (2009a), milk powder should ideally have olfactory notes similar to those of fluid milk—that is, cooked, sweet, and free of flaws like painty or grassy odors.

According to Karagul-Yüceer et al. (2001), skim milk powder (SMP) and whole milk powder (WMP) are often used as culinary additives or for direct consumption. These two types of milk powders do differ somewhat in flavor. Research on the sensory qualities of milk powder conducted by Drake et al. (2003) revealed that cooked, sweet, fragrant, salty, astringent, cardboard, potato/brothy, cereal, and animal-like characteristics are commonly found in SMP.

The presence of cooked flavors can vary depending on the milk's heat treatment (low, medium, or high) before evaporation. Some intriguing findings were obtained when milk powder samples were characterized and differentiated based on their properties using principal component analysis (Wolf, 2013).

Non-Thermal Processes

While heat treatments are considered the most efficient way to eliminate bacteria, some drawbacks have been reported, such as chemical modifications of milk ingredients or flavor changes.

The use of non-thermal processing techniques, such as microwave processing, high pressure, pulsed electric fields, microfiltration, and ultrasonication, has introduced alternatives that preserve the chemical composition of milk while inactivating pathogenic and spoilage organisms. Consumers perceive foods treated without heat as fresher or more natural than those treated with heat (Wolf, 2013).

Methods Of Odor-Flavor Detection

Factors that cause recognizable odor and taste in milk are usually measured in parts per million (ppm), parts per billion (ppb), or even parts per trillion (ppt). However, detecting and determining milk odor and taste is a challenge requiring sensitive devices (Su Xueqian et al., 2020). Raw milk entering processing machines typically contains approximately 8 ppm oxygen, which decreases to 0–3 ppm after processing, especially during de-aeration (www.anton-paar.com).

In general, the qualitative assessment of milk can be divided into two main categories: sensory assessment and instrumental analysis. Sensory assessment involves smelling, tasting, observing, listening, and touching (Kaylegian, 2013). Instrumental analysis uses specific tools to determine smell and taste. Among these, gas chromatography-olfactometry is one of the most commonly used techniques for identifying milk odors and flavors (Hoffmann, 2000; Su et al., 2020).

In addition to the methods mentioned above, there are several other diagnostic techniques in this field:

1. Single-dimensional gas chromatography
2. Multidimensional gas chromatography
3. Mass-selective detectors
4. Flame photometric detectors
5. Fourier transform infrared spectroscopy
6. Atomic emission detectors
7. Sniffing devices

These devices can evaluate samples quantitatively and qualitatively, detecting even minute amounts of substances in the tested samples (Mariaca, 1997).

Prevention of Unpleasant Milk's Odor and Taste

As the saying goes, "Prevention is better than cure." This principle is highly applicable in the dairy industry, where preventative measures can avert numerous issues and bring significant economic benefits. As discussed earlier, the basic factors influencing milk's odor and taste can be addressed to produce fresh, high-quality milk. Table 1 explains the causes and preventative measures for common issues.

Table 1: *Factors causing unpleasant milk odor – taste and the ways of its restriction (Nageotte, 1968).*

No	factors	Prevention
1	Nutrition	Feeding animal 4 hours before lactation time
2	Weeds	Eradication of weeds dryness of pasture 4-7 hours before feeding
3	Cowy or barny	Cleaning, proper ventilation
4	Salty	Remove infected cows, milk discarding
5	Rancid bitter	Proper pipelines, cool milk within 2 hours, do not freeze milk
6	Oxidized	Use only stainless steel, glass, and plastic. Milk Durham coverage

7	Malty or high-acid	Cleaning of equipment cooling of milk quickly
8	Unnatural	Use colorless and odorless drugs, and drain the whole equipment properly
9	Cow, ketosis	Herd management, discarding sick animal milk.

For example, a balanced and pleasant-smelling diet can help if odors result from animal feed. Proper milk handling before milking is crucial to prevent oxidation and exposure to sunlight. Washing the udder prior to milking prevents contamination. Additionally, carefully using approved veterinary drugs such as insecticides and limiting strong-smelling sanitizers can contribute to higher milk quality (Schroeder, 1994).

Eliminating Bad Taste and Odor in Milk

Corrective actions must be implemented when preventive measures fail to eliminate unpleasant odors and tastes in raw milk. These measures ensure milk is acceptable to consumers, producers, processors, and other stakeholders. Approaches to eliminating undesirable milk flavors can be divided into additives and physical methods.

Additives. Classical methods include adding vitamin A, approved food additives, phosphoric acid, acidifiers, polyoxyethylene, emulsifiers, stabilizers, sorbitan tristearate, calcium chloride, potassium chloride, texturizers, thickeners, and flavoring agents (Hosseine, 2016).

Physical Methods. Heat and steam vacuum treatments are among the most effective methods to combat unpleasant odors. These methods expose milk to a deodorizer or de-aeration process during production. The milk is heated to approximately 60°C and then introduced to a vacuum tank. Here, the milk is sprayed onto the tank walls, dissipating unpleasant odors. The chamber removes oxygen and other volatile compounds as steam via a vacuum pump (Farajzadeh, 2023; Jozef, 2012).

Some sources suggest a de-aeration temperature of 56°C, which is 8°C lower than milk pasteurization temperature (Yee et al., 2013). High-temperature pasteurization also removes dissolved air from milk, reducing oxidation and preventing taste alterations (Sabri et al., 2021; Larsson, 2009).

Vacuum steam processing can eliminate up to 95% of odors responsible for unpleasant tastes in milk. For example, raw milk typically contains about 10% gases, which are significantly reduced during this process (Chirlaue, 2011; ACS, 1959).

The working mechanism of air or deodorizer devices is illustrated in Figure 1, detailing the process step by step (Bylund, 1995).

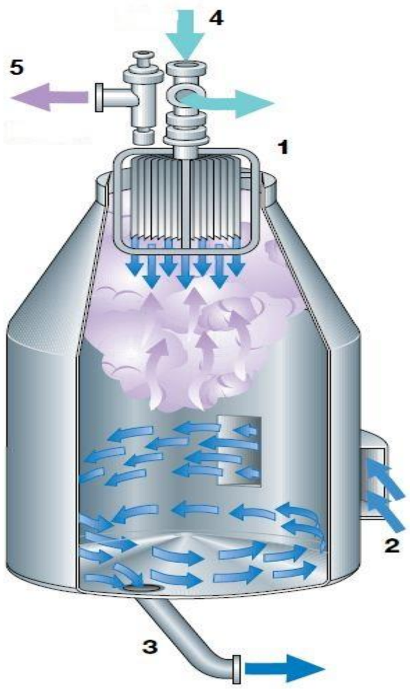

Fig.1. Valve and airflow in the deaerator machine with an internal condenser, 1- internal condenser, 2- valve entering the milk exposed to the device, 3- valve outlet with the control system, 4- cold water and 5- vacuum (Bylund, 1995)

CONCLUSION

The unpleasant smell and taste of milk remain a significant challenge for many farmers and milk dealers, often leading to economic losses due to the rejection of low-quality milk. While non-thermal processes are effective in preserving the natural taste of milk, thermal processes—such as evaporation and vacuum treatment—are highly efficient in reducing odors dissolved in the milk. Preventative measures remain the most effective and efficient approach to addressing this issue.

Additionally, using deodorizing machines in large milk collection centers offers a practical solution to eliminate unpleasant milk odors. By resolving these challenges and improving milk quality, the production of dairy products can be enhanced, ultimately boosting farmers' income and supporting the overall growth of the dairy industry.

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