Effect of Management Practices on Quality of Milk

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Abstract. Milk quality plays a decisive role in ensuring consumer safety, improving processing efficiency, and determining the profitability of dairy enterprises. Although genetics and physiology define the baseline composition of milk, the quality available at the farm level is predominantly shaped by management practices. These include milking hygiene, udder health programs, housing and bedding conditions, feeding and nutritional strategies, milking systems and equipment maintenance, and the training and knowledge of farmers. This research paper synthesizes global research evidence to critically examine how management practices affect hygienic and compositional quality indicators such as somatic cell count (SCC), total bacterial count (TBC), fat, protein, lactose, and casein fractions. Evidence demonstrates that integrated management combining hygiene, mastitis control, housing cleanliness, feeding stability, and proper milking equipment maintenance consistently enhances milk quality. Nonetheless, challenges remain, especially in smallholder contexts where limited resources constrain adoption of best practices [5].
Keywords: milk quality, management practices, hygiene, mastitis control, bacterial contamination

1 Introduction

Milk is a biologically complete food, but its nutritional richness also makes it highly perishable. Ensuring high-quality milk at farm level is essential for maintaining food safety, extending shelf life, and achieving desirable properties for processing into cheese, yogurt, and other dairy products. Quality is commonly measured by two dimensions: compositional quality (fat, protein, lactose, casein content) and hygienic quality (SCC, TBC, presence of pathogens).

While genetic and physiological factors (such as breed, lactation stage, and parity) influence baseline composition, these factors are largely non-modifiable in the short term. By contrast, management practices the day-to-day decisions related to milking, hygiene, housing, feeding, and animal health represent practical levers for improving milk quality. Numerous studies across regions have shown that poor management practices directly contribute to high SCC, bacterial contamination, and variable composition, all of which reduce milk's economic and nutritional value [12].

The aim of this paper is to synthesize available knowledge on how management practices affect milk quality. It also highlights research gaps and proposes pathways for sustainable improvements, especially in resource-limited smallholder systems.

2 Compositional traits

The key compositional traits include fat, protein, and lactose percentages. Milk fat determines energy value and influences flavor, while protein particularly casein is critical for cheese-making. Lactose is an important energy source and influences osmotic balance in milk. Stable composition is highly desirable for processors.

Milk proteins are the set of proteins present in milk (especially cow's milk, which is most studied, but many principles apply to milk of other mammals, including human milk). They provide essential amino acids, support growth and immune function, and give milk its physical and functional properties [3]. Milk proteins are primarily caseins and whey proteins; they supply essential amino acids and are a major reason milk is considered a high-quality protein source. Research has focused on protein quantity and functionality (e.g., casein fractions affecting cheese yield) and on how thermal treatments modify protein structure and digestibility. Heat-induced denaturation can alter the solubility and bioactivity of whey proteins while affecting coagulation properties important for dairy processing [6].

Milk fat is a complex mixture of triglycerides containing short-, medium- and long-chain fatty acids, and minor components (phospholipids, fat-soluble vitamins, conjugated linoleic acids CLAs). The fatty acid profile is highly responsive

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to the animal's diet: pasture feeding and PUFA-rich supplements increase the proportion of beneficial unsaturated fatty acids and CLA, while high concentrate diets increase saturated fractions. Genetic selection also shows potential for shifting fatty-acid proportions. These compositional shifts matter for human health claims and for the technological properties of dairy products [3].
Lactose is the main carbohydrate in milk and affects both caloric value and palatability. Its concentration is relatively stable across healthy animals but can decline during udder infections or severe metabolic stress, which in turn alters osmotic properties and total solids.

Milk provides essential minerals (notably calcium, phosphorus, potassium, iodine, selenium) and both fat- and water-soluble vitamins (A, D, B-group, riboflavin). The bioavailability of several of these micronutrients from milk is high because of the food matrix (e.g., calcium in casein micelles) [8]. Additionally, milk contains bioactive molecules (immunoglobulins, growth factors, milk oligosaccharides) that can support early immune function, gut colonization, and metabolic regulation. Species (cow, buffalo, goat, human) and production system account for important differences in these minor but nutritionally significant components [1]. Breed and genetic background determine baseline potentials for fat, protein, and specific fatty acids. Heritability studies indicate that selective breeding can meaningfully change compositional traits over generations, enabling targeted improvement of nutritive parameters.

Diet is among the most powerful levers to change milk nutritive quality. Fresh pasture and diets enriched with oils (e.g., linseed, fish oil) raise omega-3 and CLA contents; certain supplements can modify processing characteristics. Seasonal feed availability also drives within-year variation in vitamin and fatty-acid composition [3].

3 Hygienic quality

An indirect measure of udder health. Elevated SCC indicates inflammation, and is associated with lower lactose and altered protein fractions [2]. Total Bacterial Count (TBC) indicates microbial contamination of milk from the environment, equipment, or infected udders. High TBC reduces shelf life and raises food safety risks. Cheese yield, heat stability, and flavor are strongly affected by SCC and microbial load. High SCC reduces casein and increases serum proteins, impairing rennet coagulation and reducing cheese yield. Udder infections and elevated somatic cell counts (SCC) substantially affect milk composition: they commonly reduce lactose and solids-not-fat and alter proteins and minerals, and they degrade technological quality (poorer coagulation and cheese yield). Both clinical and subclinical infections therefore reduce nutritive and commercial value. Monitoring SCC and managing udder health remain central to maintaining nutritive quality.

4 Pre-milking teat preparation

Cleaning teats with disinfectants or single-use towels reduces the microbial load entering milk. Fore-stripping also helps identify early diseases and reduces contamination [13]. Teat dipping with iodine or chlorhexidine reduces new intramammary infections. Farms that implement this practice consistently show reduced SCC. Residues in milking machines and storage tanks harbor bacteria such as Pseudomonas, leading to spoilage. Regular cleaning with hot water and detergents is essential. A field survey in India showed that hygienic milking reduced coliform counts by up to 50% compared to farms without standardized routines [13].

5 Udder health and mastitis control

Milk quality is a function of both intrinsic factors (such as genetics and physiology) and extrinsic factors (such as management practices and hygiene). Udder health has a direct impact on milk composition, safety, and consumer acceptability [12]. Mastitis, caused mainly by bacterial infections, remains a major challenge in dairy farms, increasing somatic cell counts (SCC), reducing yield, and altering milk composition. The adoption of effective management practices is crucial to maintaining udder health and ensuring sustainable milk production. Subclinical mastitis is more prevalent than clinical mastitis and elevates SCC without visible symptoms. It reduces lactose and alters casein whey ratios. Clinical mastitis reduces yield and introduces pathogens and toxins into milk, making it unsuitable for consumption. [12] noted that systematic mastitis control programs reduced bulk-tank SCC by >30% in US herds. Somatic cell count is the primary indicator of udder health. High SCC levels reflect mastitis infections and negatively affect milk quality by reducing lactose and casein content. Cows with mastitis produce less milk, with altered fat, protein, and mineral contents. Udder health and mastitis control are integral to producing high-quality milk [14]. Effective management practices—such as hygienic milking, proper housing, balanced nutrition, and preventive veterinary care—are essential for reducing mastitis incidence and ensuring safe, marketable milk. Future advancements in precision monitoring and sustainable disease control strategies will further enhance milk quality and dairy farm profitability. Mastitis is the single most important health issue affecting both milk composition and technological quality. Intra parenchymal infection increases SCC, raises serum-derived proteins in milk (reducing casein fraction), lowers

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lactose, and shortens shelf life; it also reduces cheese yield and alters milk acidity. Effective mastitis management early detection, targeted therapy, dry-cow therapy, culling chronically infected cows, and routine monitoring of SCC is therefore central to improving milk quality at scale. Reviews of mastitis control show that integrated on-farm programs lead to sustained reductions in SCC and improved product outcomes [12].

6 Housing and bedding management

Organic bedding (straw, sawdust) tends to harbor bacteria if not changed frequently, whereas sand is considered cleaner but costlier. Dirty udders increase the risk of teat contamination during milking. Housing systems with poor drainage and ventilation also elevate infection risk. [7] found that poorly maintained housing in Moroccan dairy farms was directly linked to higher bacterial loads in milk. Heat stress, poor housing, and inadequate hygiene reduce feed intake and alter rumen function, lowering fat and protein content and increasing susceptibility to spoilage organisms. Proper cooling, ventilation, and clean milking areas reduce microbial contamination and help preserve nutrient integrity [1]. Immediate cooling after milking and sanitary storage slow microbial growth and preserve nutrient and sensory qualities. Thermal processing (pasteurization, UHT) is essential for safety; however, processing intensity affects some vitamins and certain heat-labile proteins. Modern reviews conclude that pasteurization retains the core nutritive value while improving safety, but researchers document measurable declines in specific vitamins with very high thermal loads. Fortification (e.g., with vitamin D) and targeted processing strategies are used to optimize both safety and nutrient retention [6].

7 Feeding and nutritional strategies

Pasture based diets improve fatty acid profile (higher CLA, omega-3s). Indoor, concentrate-rich diets increase yield but may dilute fat percentage. Sudden dietary shifts cause rumen imbalances leading to milk fat depression. Adequate selenium, vitamin E, and zinc improve udder immunity. [4] demonstrated that milk from pasture-fed cows had more favorable nutritional profiles compared to indoor-fed cows. Diet is among the most powerful levers to change milk nutritive quality. Fresh pasture and diets enriched with oils (e.g., linseed, fish oil) raise omega-3 and CLA contents; certain supplements can modify processing characteristics. Seasonal feed availability also drives within-year variation in vitamin and fatty-acid composition [3].

8 Milking systems and equipment maintenance

Automated milking systems (AMS) allow flexible milking but require strict hygiene management. Regular servicing and liner replacement are critical. Studies show farms that service equipment at least every 6 months have lower SCC and fewer teat-end lesions. Bucket milking is the simplest mechanized system, widely used in smallholder farms. Although cost-effective, it requires frequent handling and is more prone to contamination if cleaning is inadequate [13]. Pipeline systems transport milk directly from the cow to a bulk tank, reducing contamination risk. They are widely adopted in medium- to large-scale farms due to their efficiency and hygiene benefits [11]. Milking parlors, including herringbone, parallel, and rotary designs, allow efficient handling of large herds. These systems reduce labor requirements and improve milking speed, but require significant investment and regular maintenance [9].

9 Farmer training and record-keeping

With increasing consumer awareness and stricter food safety regulations, emphasis has shifted toward the adoption of management practices that safeguard milk quality from the farm to the market [5]. Among these practices, farmer training and record keeping have emerged as crucial components for enhancing milk hygiene, productivity, and traceability. Farmer training ensures that dairy producers understand hygienic milking techniques, feed management, and equipment sanitation. Studies have shown that trained farmers adopt improved milking hygiene, which reduces bacterial load in milk and lowers somatic cell counts. Well designed training programs emphasize disease prevention, which directly affect milk quality and safety [7]. Knowledge transfer through extension services is essential for improving milk quality, especially in smallholder systems. Record-keeping enables farmers to track SCC trends, mastitis incidence, and equipment servicing, allowing early interventions.

10 Integrated management approaches

Individual practices improve quality, but the best outcomes occur when practices are combined. Integrated herd health programs have been shown to consistently reduce bulk-tank SCC and TBC, while improving fat and protein stability. Effective cleaning is essential to prevent bacterial growth in milking equipment. Cleaning involves a cycle of rinsing, washing with detergents, and sanitization before milking [7]. Biofilm formation in inadequately cleaned pipelines is a major concern for milk quality. The vacuum system regulates milk flow, and any malfunction may lead to teat injuries or incomplete milking. Regular testing of pulsators, liners, and vacuum levels is necessary to ensure animal comfort [11], Balanced feeding strategies ensure optimum milk yield and reproductive efficiency. Integration of forage-based diets with concentrate supplementation improves rumen health and feed efficiency [10]. Use of Total Mixed Rations (TMR) and precision feeding reduces nutrient wastage and environmental pollution.

11 Conclusion

Management practices have a profound influence on milk quality. Evidence demonstrates that improved hygiene, mastitis control, clean housing, stable feeding, and well-maintained equipment reduce microbial contamination and stabilize composition. However, adoption of best practices remains uneven, particularly among smallholders. Policymakers, extension agents, and processors must work collaboratively to promote affordable, integrated solutions that enhance milk quality and farmer profitability.

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