Food Safety Issues in Dairy Production in Senegal: Challenges and Pragmatic Solutions for the Dairy Value Chain

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SUMMARY

Milk plays a vital role in feeding Senegal's rural and urban populations and are advised as part of a balanced diet. Therefore, achieving self-sufficiency in animal products, particularly in the dairy value chain, has been the top priority of the Senegalese government.

This review looks into challenges associated with milk production, including climate change, poor milk quality, and sanitation hazards, and recommends preemptive solutions to the existing milk production system. Since milk is traditionally consumed raw or fermented, microbial food safety plays an essential role. Pathogens such as *Mycobacterium bovis*, *Brucella abortus*, and *Coxiella burnettii* are of great public health concern. Due to traditional beliefs, there is a lack of awareness about milk-borne hazards. Most men consider milk could not transmit any illness; as a result, farmers practice risky milk handling. Data are scarce on the potential food safety issues and the existence of commonly detected pathogens, such as *Salmonella* spp., *Escherichia coli*, *Staphylococcus* spp., and *Listeria monocytogenes*.

In conclusion, it is imperative to have a baseline understanding of microbial risks and how their presence in food can be avoided or kept within acceptable limits. One must account for the prevalence and distribution of pathogens in Senegal's dairy production system.

OVERVIEW

Senegal is a low-to-middle-income country in West Africa whose economy is primarily agriculture-based. The Senegalese government has prioritized achieving self-sufficiency in animal products, particularly in the dairy value chain *(3, 4, 7, 44)*. As a result, in recent years, there has been a continuous growth in the animal population, accompanied by increased meat and milk supplies. Current data show improvement in establishing the 'dairy hub' for milk collection, however, 46% of the population live in poverty, and 17% are affected by food insecurity *(56)*. An estimated 25% of the country's children suffer stunted growth because of poor nutrition.

A typical Senegalese cow produces 0.6 liters of milk per day, and the country's average milk production yield is one of the lowest globally *(56)*. The country is only 66% self-sufficient in milk production, mainly due to the genetic limitations of local breeds and poor knowledge of farming best practices. Most (91%) of the locally produced milk is handled and marketed through traditional methods without industrial processing, thus making it challenging for local dairy producers to compete with imported milk. Milk has significant economic, sociological and nutritional importance *(8)*; it is produced daily, sold for cash, and has a quick turnover. It is a cash crop that allows families to purchase other consumables, contributing significantly to family food security *(10)*.

An estimated 0.6 million Senegal dairy cows produce 193 kg of milk annually, and most of the production occurs in small-scale extensive farming systems. Intensive dairy systems are still rare and are mainly located in the Dakar region. Senegal's annual milk production of approximately 123,766 tons is primarily used for household consumption and sales *(15)*. According to the National Association of Statistics and Demography, annual production in 2019 was approximately 264.6 million liters compared to 249.4 million in 2018. This increase of 6.1% is attributed to the introduction of modern livestock production using pure exotic breeds, with a net progression of 45.7 million liters against 22 million liters in 2018. However, the increase in milk production was negated by the poor performance noted in the mixed-type breeding activity (−5.0%), as well as that of the pastoral type (−2.9%) *(3)*.

Meanwhile, a substantial increase in demand for dairy products is noted due to a link between urbanization and the opening of international markets, which boosts importation. To better document these changes, a study was carried out to analyze the supply of dairy products from the local and imported dairy sectors. Dairy processors collect less than 10% of all milk produced in Senegal, equivalent to 10,204 tons of milk annually, despite the existence of 200,000 dairy farmers. The daily consumption of milk products (primarily

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milk) is approximately 22 kg per capita per year *(15)*. Over the last decade, milk and dairy product consumption has increased dramatically, and small processing units supply a large portion of the local production. Milk and milk products are vital in feeding Senegal's rural and urban populations. Eighty percent of the milk produced in rural areas is consumed locally. Despite a campaign titled "Mon lait est local" (i.e., my milk is local) to promote domestic consumption of milk in West African countries, including Senegal, the majority of the milk consumed is imported from Europe in powdered form *(8)*. Senegal imports 26,104 tons of milk equivalent annually (53% of this is dried milk powder). Dairy imports pose a significant burden on the country's trade balance, amounting to USD 121 million in 2012 *(22)*.

The dairy herd comprises native and exotic cattle breeds and hybrids between them. Because of its trypanotolerance, the Zebu Gobra is usually found in the Sahelian region of the country (north and center) and the taurine N'Dama in the south and east (Sahelo-Sudanean zone). The Djakoré, a genetic type emerging from the interbreeding of the Zebu Gobra and the N'Dama and taurine lines, is found in the transition zones between these two native habitats. Whereas local breeds have good carcass dressing potential, they have little dairy potential. Therefore, exotic breeds, namely Jersey, Montbeliard, Holstein, and Gir, have been introduced to promote a higher milk supply for urban and suburban populations *(65)*. Over 2 years, data from 220 smallholder dairy cattle farms suggested that it was most cost-beneficial for such farms to keep crossbreeds of indigenous Zebu and exotic *Bos taurus* *(44)*. Improvements in dairy cattle genetics and in management have increased milk production and cow reproductive performance and, subsequently, have improved the livelihoods of the rural poor and have increased livestock production self-sufficiency in Senegal *(16)*.

Senegal is divided into three different dairy production systems *(Fig. 1)*: (i) the extensive pastoral system, (ii) the agropastoral system, and, most recently, (iii) the intensive system *(19)*. Many factors affect milk production: climate changes, water resources, pasture, lack of veterinary services, and problems with dairy farmers' knowledge, attitudes, and practices regarding milk-borne pathogens *(65)*. Due to consumer demands for safe and high-quality milk, it was recommended that dairy producers, retailers, and manufacturers take responsibility for producing and marketing healthy milk and milk products *(2)*.

Role of climate change in milk production

Senegal has a tropical hot and humid climate with a dry season from November to May and a rainy season from June to October *(65)*. Variations in temperature and the frequency of extreme climate events directly affect livestock performance and welfare. They indirectly affect animals by changes in feed and grassland availability and

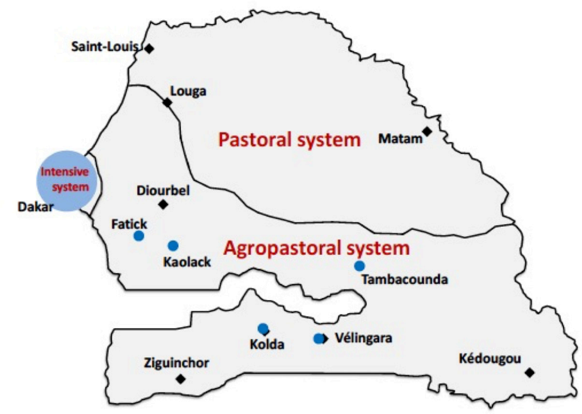

Figure 1. Dairy production system Senegal *(19)*.

the distribution of pests and parasites *(25)*. Heat stress in cattle is associated with higher temperatures, can negatively impact milk production *(11, 31)*, fertility, and health *(32)*; it also increases the chance of mortality *(70)*. Heat stress occurs when animals, exposed to temperatures outside their thermal comfort zone, cannot eliminate enough heat to maintain thermal equilibrium *(6)*. Therefore, an adverse climate is costly to the dairy industry, with increased management interventions and lost productivity *(71)*. The indigenous milk production system is structured around climatic conditions, with substantial production during the rainy season and a slowdown or even cessation of operation during the dry season, which lasts for 7 months. As a result, dairy farmers are more concerned with the lack of food for their animals than the safety of milk and milk products. Climate change directly affects the amount and seasonality of production *(16)*.

One of the effects of climate change is the scarcity of drinking water. Water makes up 87% of milk. Therefore, a lack of clean, fresh, and high-quality water can reduce milk production faster than any nutrient shortage *(69)*. Dairy cows consume approximately 45.4 liters (12 gal) of water per 0.45 kg (1 lb) of milk produced, and drinking water meets 80 to 90% of these requirements, with the balance coming from moisture in feeds. In Senegal, dairy cows drink approximately 37.85 to 56.78 liters (10 to 15 gal) of water per day when the temperature exceeds 21.11°C and the humidity rises. Heat-stressed cattle require 1.2 to 2 times more water than cattle housed under thermal neutral temperature and humidity *(72)*. Low water intake raises hematocrit and blood urea, reducing the respiratory rate and rumen contractions *(42)*. This, in turn, decreases body weight and milk output *(42, 68)* and induces conflicts among water users *(68)*. Unfortunately, on modern dairy farms, the water intake of dairy cows is rarely regarded as a potential limiting factor for milk output.

As a result, water quantity and quality are not adequately monitored, despite attention to other nutrients *(9)*.

Under harsh tropical environmental conditions, cattle production is limited by the quality and quantity of pastoral resources, mainly during the dry season *(20)*. Cattle that suffer from malnutrition mobilize their bodily reserves, which negatively impacting productivity in the nutrient-deficient dry season *(17)*. However, the influence of body condition score on fat reserve mobilization for milk supply and calf growth in late pregnancy and early lactation is unknown. Calving body condition score is closely linked to milk output in dairy cattle *(63)*. However, prepartum body condition score change and calving body condition score do not affect milk yield or calf performance in beef herds *(60)*. It was further reported that deficiencies in prenatal and postnatal nutrition negatively impacts calf birth weight and milk supply *(36)*. Local breeds are dual-purpose cattle that survive in tropical conditions. Although pasture quality has been proven to affect milk yield *(1)*, no research has been done on the links between cow body condition, calf growth, and milk production in Senegal. The most common cattle in southern Senegal are N'Dama taurine, a small trypanotolerant breed from neighboring Guinea *(50)*. Local breeds are less vulnerable to environmental variability than European breeds and can reproduce even when there is a food shortage *(50)*. However, the body reserves of N'Dama cows differ among individuals and within reproductive stages and seasons *(20)*; these variations in nutritional status may impact their milk output, calf growth and mortality, and cow fertility.

Food safety issues in milk production and a review of the organization of milk production

Milk can harbor several pathogenic microorganisms. As in other low-to-middle-income countries, the dairy industry in Senegal is growing; the number of farms is expanding to meet rapidly growing demand in the cities. However, most milk is still produced in the informal sector and comes from small processors spread all over the country *(8)*. Little is known about the consumption of milk and milk products or the knowledge, awareness, and practices of consumers in the informal dairy supply chains *(44)*.

Data regarding potential food safety issues and the microbiological quality of milk and milk products in Senegal are scarce. However, 85 bulk milk samples collected from 68 smallholder dairy farms throughout the territory revealed poor microbial quality of raw and pasteurized milk *(13)*. Of samples collected for this study, 93% of pasteurized, 92% of raw, and 81% of sour milk samples failed to meet official standards. Pathogens detected were *Coxiella burnetii* (6 of 41, 15%), which seems to be endemic in Senegal, and coagulase-positive *Staphylococcus* spp. (18 of 70, 26%); 9 of 10 samples produced enterotoxigenic strains and *Salmonella* Johannesburg *(13)*. However, studies conducted in 20 African countries, including Senegal, revealed pathogens such as *Escherichia coli* (O157:H7, Shiga toxin-producing *E. coli*), *Staphylococcus* aureus, *Brucella* spp., *Bacillus cereus, Listeria monocytogenes*, *Salmonella enterica*, and *Mycobacterium bovis* *(55)*. This report demonstrated the abundance of pathogens in Senegal, including *C. burnetii* and *Brucella* spp. *(55)*. Traditional pathogens of concern in milk and dairy products, including *M. bovis, Brucella abortus,* and *C. burnettii*, have been mainly eradicated from the industrialized world. However, they have persisted in Senegal and have re-emerged in some African countries *(47, 51, 58)*.

The Senegalese National Plan for agriculture, livestock, and food security (milk, meat, and eggs), envisages the expansion and modernization of the dairy sector. These plans are predicted to accelerate rapid changes in the Senegalese dairy sector: the expansion of dairy herds, changes in breed composition, and changes in the ecology of endemic conditions, including milkborne pathogens *(16)*. A study by the same authors in Dakar, Thies, and Fatick districts in Senegal revealed a disparity of knowledge between women and men regarding milk-borne pathogens. Women seem to know more about milk-borne infections than other zoonotic diseases. In contrast, most men believed milk could not transmit illness. Dairy farmers and traditional milk processors generally believed that milk was safe soon after milking and that boiling was inconsequential *(16)*. Malaria is still a public health issue in Senegal; the local community uses the term "malaria" to denote any disease with fever as a symptom. Infections classified as "malaria" could actually be due to transmission of zoonotic pathogens from dairy animals and dairy products, such as brucellosis, Q fever, or other bacterial and viral diseases *(64)*.

Animal illnesses cause death and decrease productivity in dairy herds worldwide, resulting in significant financial losses. Although production disorders, such as mastitis and external and internal parasites, do not usually kill the affected animal, they lower the system's efficiency. Diseases can impact dairy productivity by reducing milk yield, decreasing fertility, delaying puberty, lowering milk quality, and decreasing feed conversion. Diseases such as tuberculosis and brucellosis in dairy animals may also threaten human health *(51)*, and they pose a severe threat to small-scale dairy production in developing nations for several reasons: high prevalence of infections; poor understanding of methods to prevent, manage, and control illnesses; and difficulty in accessing affordable, available, and suitable animal health services. Small-scale dairy farmers invest little in animal health, particularly disease prevention *(23)*. A small-scale dairy producer with limited resources may find that losing a single animal to disease significantly impacts their household economy.

The health requirements of dairy species and breeds vary depending on their physical and physiological traits. Animals that are exposed to a new environment lack locally acquired immunity and may be vulnerable to endemic diseases specific to the new locale *(23)*. Therefore, it is critical to select dairy cows that can adapt to the local climate, consume available resources, and resist endemic illnesses and parasites. Intensive dairy animals are more susceptible to transmissible disease agents, whereas extensive dairy animals are more susceptible to parasitic infections.

Means of collecting milk and potential sanitation hazards

Milk and milk products are consumed in different forms by humans worldwide. When it is secreted into the alveoli of the udder, milk is nearly sterile. However, from that point on in the steps of production, microbial contamination may occur from various sources *(37, 45)*. Poor sanitary methods in pre-milking udder preparation, suboptimal hygiene of milk handlers, and inadequate sanitation practices linked with milking and storage equipment contribute to raw milk contamination at several crucial stages *(26)*. As a result, commercial milk is susceptible to contamination by many pathogenic bacteria that can cause human diseases during production, processing, and manufacturing operations; it may transmit bacterial (brucellosis, tuberculosis, salmonellosis, listeriosis, rickettsia, Q fever), viral (hepatitis, foot-and-mouth disease), or parasitological (toxoplasmosis, giardiasis) diseases *(26)*.

Milk is an excellent culture and protection medium for certain microorganisms, especially bacterial pathogens, whose multiplication is primarily influenced by temperature, competing microorganisms, and their metabolic products *(43)*. Lactic acid producers, which promote quick souring, are usually the principal contaminants of milk that is produced under inadequate hygienic circumstances and is not chilled promptly. Although lactic acid inhibits harmful germs, it cannot be relied upon to create a safe milk product *(32)*. In addition, drinking raw milk can transmit many pathogenic infections to humans, among them brucellosis *(7)*, salmonellosis, listeriosis, *E. coli* infections *(12)*. Pathogenic organisms in milk can come from various sources, including the cow, human handlers, and the environment. For example, mastitis-affected cows release many pathogens into their milk, including *S. aureus, E. coli,* and *Clostridium perfringens*. In a farm environment, microorganisms from the soil, litter, feed, water, feces, and other substances regularly contaminate the surface of the udder and teats, as well as the hair and skin of cows, thus entering the milk during milking.

Equipment for milking, transport, and storage is an essential part of the dairy value chain. Calabashes and plastic buckets with lids are commonly used for milking and milk storage. Large volumes of milk are typically transported in used 20-liter vegetable oil jerry cans because they prevent leakage *(33)*. However, jerry cans are difficult to clean properly; they have an opening that is too small to allow hands or cleaning instruments to enter. Some milkers and milk traders use cloth to keep out flies and dirt, but these cloths are not adequately cleaned and do not reliably exclude infectious agents. At markets, milk merchants utilize spoons or cups as measuring tools, and these are not thoroughly cleaned. Most of the time, they are simply wiped with a cloth. Some sellers even give a skeptical customer a spoonful of sour milk to taste to prove their product quality, which increases the contamination level of their products, already high in bacterial load, throughout the day *(5, 41)* *(Fig. 2)*.

Typically, equipment for milk collecting and handling is rinsed in cold water with soap and dried in the sun. In

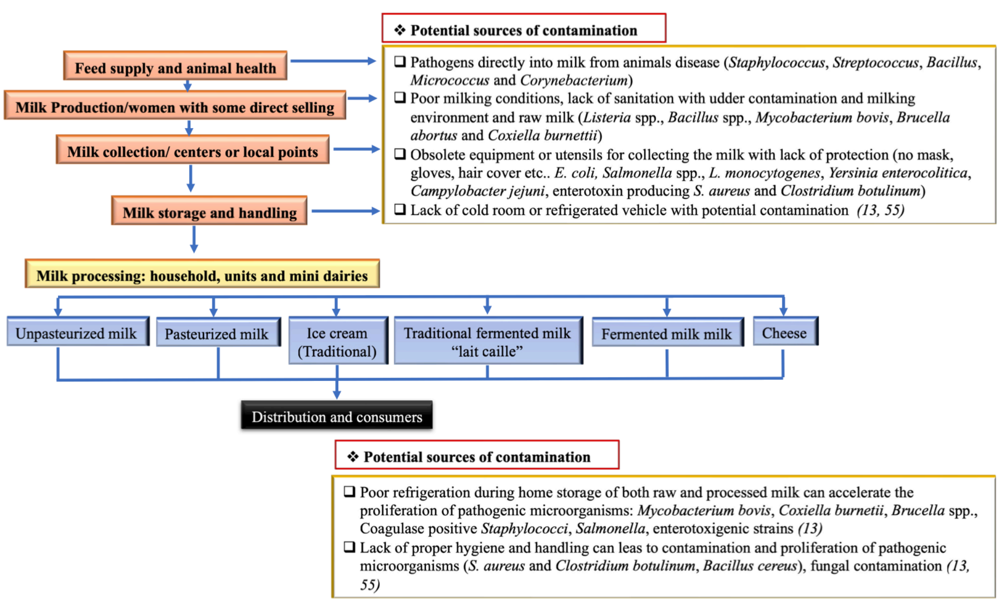

Figure 2. Chart of the Senegalese milk chain with potential sources of contamination.

addition to these sources of contamination, high ambient temperatures of around 30°C and a lack of cooling facilities create ideal conditions for bacteria to multiply rapidly. As a result, fresh milk ferments quickly (in 2 to 3 h), and pathogenic bacteria reach infective levels rapidly. This situation has improved marginally in Kolda; pasteurization has been implemented, and milk producers and collectors have received hygiene training *(33)*.

In underdeveloped tropical countries with high ambient temperatures, raw milk spoils quickly during storage and transportation due to a lack of refrigeration facilities at the farm and in the home *(28)*. Microorganisms are also spread as a result of unsanitary milking processes and via equipment for milking, filtering, cooling, storing, or distributing milk. Inadequate cleaning and disinfection after use makes the issue of cross-contamination worse. Milk residues on equipment and utensil surfaces could serve as a source of nutrients and provide ideal growth conditions for numerous bacteria, including those causing diseases *(45)*. In addition, individuals who milk animals or handle milk can introduce additional pathogenic organisms into the milk.

Natural fermented milk, known as "lait caillé," is an integral part of the daily diet in many parts of Senegal. Recent ethnographic research in northern Senegal has documented the role of lait caillé in supplementary feeding diets for newborns and young children *(57)*. The microbial community in milk is critical for the finished product's shelf life, safety, and nutritional and organoleptic qualities. Natural fermented milk is a cost-effective way to administer probiotic bacteria with specific health benefits, especially in resource-constrained areas *(66)*. Consumption of probiotic fermented milk presents a promising opportunity to address enteric disease and malnutrition among children in northern Senegal, where 18% of children under the age of five are stunted, 9% are wasted, and 18% are underweight *(3, 24)*.

The only method to ensure that germs present in raw milk are killed and that the milk is safe is to pasteurize it or subject it to more severe heat treatments. Pasteurization extends the shelf life of milk by reducing the load of nonpathogenic microorganisms that cause spoilage *(61)*. However, due to contamination during storage and preparation, harmful bacteria can occasionally be discovered in pasteurized milk and milk products *(30, 49)*.

Gonçalves and colleagues *(29)* reported potential milk contamination by aflatoxin B1 from different sources of *Saccharomyces cerevisiae* biomass obtained from various plant materials, such as sugarcane cell wall, dried yeast, and autolyzed yeast. In Senegal, ruminants (cows, sheep, and goats) are mainly fed on grass, fodder, and cakes made from herbs. The latter used mostly peanut shells that could present potential risks when contaminated with aflatoxins. Aflatoxin M1 is found in the milk of animals fed with contaminated feed (cake made from herbs, etc.), and it could be associated with hepatocarcinoma risk exposure in the dairy farming population of Malawi *(53)*. At high doses, other aflatoxins, such as B1, can cause acute poisoning (aflatoxicosis) that can be life-threatening, usually due to liver damage. Toxicological characterization, particularly the presence of aflatoxin M1 and others (B1), is lacking for locally produced milk, which is often transformed into curd milk products.

Implementation of adequate hygienic milking techniques at the farm is vital to lower the initial bacterial load in raw milk. Before milking, udders should be cleansed with chlorine solution and rubbed dry, and milkers should likewise wash their hands. Clean equipment and a clean milking station should also be prioritized. All equipment that comes into contact with milk should be cleaned and washed with soap *(33, 48)*.

Strategic solutions to reduce hazards related to milk collection

In Senegal, milk is traditionally consumed raw or fermented *(55)*. Milk from diseased cows may harbor pathogenic zoonotic agents or be contaminated due to unsanitary handling and unhygienic treatment at the farm or in the marketplace. Although milk can be harmful to human health under certain circumstances, mainly when consumed raw, there are limited data available about milk quality. It is essential to investigate the quantity, quality, and safety of milk to improve the nutrition of an expanding population in urban and peri-urban areas and the marketing of milk and derived products *(59)*.

Microbial contamination of milk can come from inside the udder, the surface of the teats and udder, and the milk handling and storage equipment *(62)*. Cleaning and disinfecting equipment, teats, and udders before and after milking can help reduce contamination *(52)*. In Senegal, milking is commonly done in the morning and evening. Unfortunately, cleaning the udder before milking or thoroughly washing the hands is not customary. Therefore, bacteria can enter the milk through the cow's udder or the milker's hands during the milking process.

Further contamination comes from flies that land in the milk. Milk collectors buy milk at the farm gate, carry it to the marketplaces, and then sell it to milk merchants in large quantities, often 5 or 10 L. The time collectors spend transporting milk to the market ranges from less than 1 h to more than 5 h. Public transportation, bicycles, or horse and donkey carts are used, depending on distance and availability. Foot travel is used for shorter distances *(67)*.

Important alternatives in ensuring food safety issues in milk production

Environmental impacts, markets, health (human health, food safety, and animal health), and institutional arrangements must all be addressed to mitigate the adverse effects and maximize the positive contributions of sustainable livestock intensification *(34)*. Factors that affect foodborne pathogens in milk include the health and hygiene of the dairy stock, the environment, raw milk quality, milking, pre-storage conditions, available storage facilities, and the staff *(18)*. Factors that may influence the microbiological load include herd size, location of milk collection center, the temperature of the milk at delivery, availability of a cold chain, and time of transportation *(39)*.

Bacteria cause more than 90% of all dairy-related illnesses, mainly attributable to the consumption of unpasteurized milk *(27)*. High total bacterial count and somatic cell count levels have resulted in milk production losses of up to 20% in certain herds *(40, 54)*. Thus, testing raw milk for microbiological quality, water adulteration, and the prevalence of mastitis in the herd is critical to ensuring safety and quality *(46)*.

Milk safety has received much interest in both developed and developing areas in recent years. To assist smallholders in producing safe milk of acceptable quality, relevant experiences, practices, and other successful or sustainable techniques must be examined. In addition, lessons on quality milk production and food safety assurance systems (regulations and quality control components) can be gathered from other nations to establish appropriate solutions *(40)*. As a model taken from other African countries like Kenya, official recognition of informal markets through certification-based training in safety and quality could positively benefit producers and consumers *(38)*.

Attention to animal health, milking hygiene, nutrition, animal welfare, the environment, and socioeconomic management is recommended for acceptable dairy farming practice. Control of microbial contaminants in feed, facility hygiene, cleaning of cows, good animal health management to avoid mastitis, effective cleaning and disinfection procedures of milking equipment, and rapid cooling of milk to temperatures of 4°C or less are all critical at the farm *(27)*. The use of agricultural chemicals, veterinary treatments, animal feed, and the identification of individual animals all require traceability and record keeping *(14)*. The utilization of the lactoperoxidase enzyme system's antibacterial activity to extend shelf life and eliminate pathogens has been successfully tested in countries such as Kenya, Sri Lanka, and Mexico *(22)*. The success of this system is dependent on good hygienic standards in milk production. In conjunction with good hygienic practices, Flynn and colleagues *(21)*, confirmed that use of lactoperoxidase can inhibit the growth of pathogenic bacteria such as *L. monocytogenes* in milk and milk products, primarily cheese. Other methods for extending the shelf life of raw milk include thermal treatment and the addition of carbon dioxide *(35)*.

CONCLUSION

The insights we gained into the knowledge, awareness, and practices of key stakeholders in Senegal will facilitate efficient strategies to control or implement potential mitigation measures to ensure the quality of milk produced. The findings suggest that to implement pre- and postharvest control measures for foodborne illness, there is a need to use culturally adapted strategies, good communication, and education. Strengthening health education on zoonoses and food safety will contribute to a safer dairy value chain. In addition, the promotion of the milk production potential of local breeds will help mitigate the domination of imported powdered milk and promote the use and consumption of local milk and dairy products.

The dairy value chain holds great promise for improving household welfare and human and animal health and nutrition, increasing youth employment, and empowering women. Investments in improving quality and safety from production to consumption (from the cow to the cup) will improve the competitiveness of the Senegalese national dairy value chain and generate widespread social benefits. Clearly, food safety management requires an understanding of microbiological hazards and how to prevent them in foods or keep them within tolerable levels. Knowledge of the prevalence and distribution of pathogens associated with dairy production practices in Senegal will help in adoption of specific methods for rapid and reliable detection of specific bacterial pathogens related to milk, dairy products, and dairy-associated environments. A major emphasis has to be given to training youth and women. Women play a key role in milk production; their greater knowledge of hygienic practices in maintaining dairy cows, pre- and post-milking sanitization of the udders, and recognition of diseased animals, including mastitis, will promote the safety of the dairy value chain in Senegal. A more transformative approach is to raise student awareness of food safety issues, using food safety education programs at the elementary school level that incorporate basic concepts into school curricula. This will encourage and educate lifelong safe food handling behaviors among the farming community.

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