Microbiological Hazards in Dairy

Subjects: Microbiology

Contributor: James Owusu-Kwarteng

In Africa, milk production, processing and consumption are integral part of the traditional food supply, with dairy products being a staple component of recommended healthy diets. In this article, we highlight the main microbial food safety hazards in the dairy chain in African. These include risk factors associated with various steps in the dairy chain including primary production, milk collection, storage, packaging, transportation and distribution, traditional milk processing as well as consumer practices.

Keywords: Food safety ; mastitis ; fermentation ; pathogens

1. Introduction

From a healthy animal, raw milk is expected to harbour no pathogens at the point of collection. However, this is seldom the case. Generally, pathogenic microorganisms can contaminate raw milk in two ways. First, endogenous contamination occurs when milk is contaminated by a direct transfer of pathogens from the blood (systemic infection) of an infected animal into the milk, or via an infection in the udder. The second means by which fresh milk can be contaminated, known as exogenous contamination, occurs where milk is contaminated during or after collection by animal faeces, the exterior of the udder and teats, the skin, and other environmental sources [1]. Table 1 summarizes important risk factors and their implications for milk safety.

Table 1. Major microbiological risk factors and their implications for safety in the dairy chain in Africa.

Step in Dairy Chain	Important Risk Factors	Implications for Milk Safety
Primary production	• Diseases (mastitis) • Housing, bedding and husbandry • Feed and water quality • Waste management	• Increased shedding of pathogens directly into milk from diseased animals (including asymptomatic carriers). • Poor housing and husbandry practices increase the risk of udder contamination due to high stocking, concentration of waste, stress and soiled bedding, leading to contamination of milking environment and raw milk. • Increased risk of milk contamination can result from using poor quality water for stock drinking, teat washing and cleaning. • Contaminated or poorly prepared feed may increase faecal shedding of pathogens into milk and milking environment.
Milk collection	• Milking practices • Equipment cleaning • Personnel hygiene	• Poor milking practices, including dirty, chapped or cracked teats, insufficient cleaning and maintenance of milking equipment, and poor personnel hygiene can lead to direct contamination of raw milk with pathogens.

Step in Dairy Chain	Important Risk Factors	Implications for Milk Safety
Raw milk storage	• Availability and efficiency of cold storage facilities	• Inappropriate temperature control of raw milk, coupled with the usually high temperature in the region and erratic power supply, can lead to accelerated growth of pathogens in milk during storage.
Packaging	• Packaging Equipment and material	• Poor packaging, inappropriate packaging materials and poor hygiene can contribute to cross contamination of milk or open up milk to contamination from the environment.
Transportation and distribution	• Transportation mode • Road network between milk collection centres and market centres • Maintenance of cold chain	• Transporting of raw milk between farms and market centres by foot, bicycles, motorbikes or other means without a proper cold chain enables growth of pathogens. • Poor road network systems increase the time for transportation and distribution of raw milk, and coupled with poor cold chain facilities, allows the rapid growth of pathogens in raw milk.
Traditional milk processing	• Pasteurization/thermal treatment • Fermentation practices • Personnel hygiene and sanitation of processing environment.	• Inadequate pasteurization temperatures may not be able to eliminate pathogens in already contaminated milk, and may even encourage the faster growth of pathogens. • Spontaneous fermentations (without properly defined starter cultures), coupled with poor time/temperature controls can expose fermented products to pathogenic microorganisms. • Poor sanitation of processing environments and personal hygiene by milk processors can lead to a direct contamination of processed milk products with pathogenic microorganisms.
Consumer practices	• Storage temperature at home storage • Adherence to handling instructions and good personal hygiene	• Poor refrigeration during home storage of both raw and processed milk can accelerate the proliferation of pathogenic microorganisms. • Lack of proper hygiene and nonadherence to handling instructions can lead to contamination and proliferation of pathogenic microorganisms.

2. Risk Factors for Microbiological Hazards in Dairy Production and Processing in Africa

During the primary production stage, pathogens can contaminate milk through various routes. Animal feed and drinking water often serve as sources of microbial contamination. Predominant among the dairy production systems in Africa are the rural smallholder dairies in which farm animals are fed on grass, crop residues and cultivated fodder, or they roam the land in search of grazing grounds and water. Consequently, the microbiological quality of feed and water for dairy animals are not routinely assessed under these systems, and therefore there is a high risk for the ingestion of contaminated feed and water by dairy animals in Africa. Upon ingestion of contaminated water or feed, surviving (spore-formers) pathogens

can be expelled into the farm environment and subsequently attach to teats and udder of dairy animals. Apart from contaminating the external surfaces of udder and teats, several potential pathogens including the genera *Staphylococcus*, *Streptococcus*, *Bacillus*, *Micrococcus*, and *Corynebacterium* can colonize the mammary glands of dairy animals even without any disease symptoms [2].

Mastitis, an inflammation of the mammary glands and udder tissues, is caused by a large variety of common bacteria, fungi, mycoplasmas and algae [3] infecting the mammary glands of dairy animals. Mastitis adversely affects animal health, milk quality, consumer safety, and can lead to great economic losses for milk production [4][5][6]. In sub-Sahara Africa, both subclinical mastitis (SCM) and clinical mastitis (CM) among dairy cows have been reported with prevalence rates in the range of 16.1%–90.3% and 4.8%–25.5%, respectively [7][8][9]. A recent report indicates that the prevalence of subclinical mastitis among dairy cows in some districts in Rwanda is 50.4% and the milk collected from positive mastitis cows were found to harbour coagulase negative Staphylococci (51.5%), *Staphylococcus aureus* (20.6%), *Streptococcus* species (10.3%), *Bacillus* species (10.3%), *Streptococcus agalactiae* (5.8%), and *Escherichia coli* (1.5%) [10]. Mastitis among dairy herds is a major constraint, and the disease has been identified as a primary cause of poor-quality and compromises the safety of raw milk in Ethiopia [11]. Generally, milk can easily become contaminated before it is secreted from the udder owing to mastitis. Although microbial contamination of milk during milking is difficult to completely avoid [12], it is of utmost importance to maintain a very high level of hygiene in dairy farming practices and proper cleaning of teats during milking for good udder health and optimum milk quality, and to ensure safety [13][14].

Once milk is secreted from the udder, it can be contaminated from several sources including air, faeces, bedding material, soil, feed, water, equipment, animal hides and people. A critical factor affecting milk safety is milking hygiene. Adequate milking hygiene potentially reduces the contaminating microorganisms and prevents them from inhabiting the immediate environment or skin of the animals, hands personnel and milking equipment, thereby minimizing their spread during milking [15]. High prevalence of pathogens in raw milk and occurrence of mastitis have previously been recorded in farms that practiced poor milking hygiene in Africa [9][16][17][18]. The dairy farm environment can be a reservoir of foodborne pathogens and serve as a major source of microbial contamination of raw milk due to direct contact with the milk. The use unsterilized collection vessels (containers) and other practices such as milking with unsanitized bare hands and allowing calves to feed without cleaning the teats of udders, expose milk to microbial contamination. In most small-scale milk production farms in Africa, there are no strict implementations of procedures for cleaning and disinfection of materials used during production processes, from milking to the sales of final products. While most foodborne pathogens such as *E. coli*, *Salmonella* spp. and *Campylobacter* spp. inhabit the ruminant intestinal tract, others including *Listeria* spp. and *Bacillus* spp. are widespread in nature and live in soils and plant environments. Thus, these environmental microorganisms can contaminate the milk by direct contact or through milking equipment and personnel on the farm if good hygiene management practices are not followed. Additionally, intentional adulterated of raw milk with contaminated water has been reported [19], a practice that potentially serves as another major source of pathogenic microorganisms in raw milk.

Storage and transportation of raw milk immediately after milking through to point of sale or processing are critical for safety and quality. In order to prevent proliferation of pathogens that contaminate freshly collected milk, there should be strict time and temperature controls between the milking and the processing of dairy products. Ideally, raw milk should be immediately cooled to below 4 °C to prevent microbial growth and ensure high-quality, safe milk for processing and consumption. This is in practice not possible for most small-scale producers in Africa, and therefore pasteurisation and sterilization of the milk are strongly recommended. This is unfortunately often not the case. Modern cooling facilities including mechanical refrigeration or cooling tanks are not available to the many small-scale dairy producers for reasons such as high initial investment and running costs and technical problems, including the lack or unreliable supply of electricity. Additionally, the majority of raw milk producers in Africa are mostly located in remote rural areas with poor road networks making it difficult to transport milk to urban markets and small-scale processing units. Subsequently, raw milk is often transported from the farm to small-scale processing units in urban market centres by bicycles, motorcycles, animals (donkeys), or by foot. The usual high ambient temperatures, often reaching 35–42 °C in most parts of sub-Sahara Africa, highlight the problem by accelerating the growth of spoilage and pathogenic microorganisms during transportation of raw milk.

The majority of milk produced in Africa is processed into a variety of traditional milk products by small-scale processing units or processors. The final products including spontaneously fermented yoghurt-like milk, traditional cheeses and butter, are produced with slight variations in processing methods depending on country or local region, which is affected by local tastes, dietary habits or culinary traditions [20][21]. The production of African traditional dairy products is based on recipes handed down from one generation to another, and processors often do not have access to formal training but learn by seeing, hearing and practicing [21]. Small-scale processors of traditional milk products often lack pasteurization,

storage and packaging facilities and do not adhere to good manufacturing and hygiene practices (GMP/GHPs), including the implementation of starter culture procedures for milk fermentation. The processing of milk into yoghurts and other fermented products in most parts of Africa relies on spontaneous fermentation or back-slopping where a part of a previous batch of a fermented product is used to inoculate the new batch [21][22][23]. Consequently, traditional African fermented milk products may be susceptible to contamination with human pathogens of public health concerns due to the lack of proper control measures and adherence to good manufacturing practices (GMP) in the traditional fermentation processes.

References

1. C. Verraes; G. Vlaemynck; S. Van Weyenberg; Lieven De Zutter; G. Daube; M. Sindic; M. Uyttendaele; L. Herman; A review of the microbiological hazards of dairy products made from raw milk. *International Dairy Journal* **2015**, *50*, 32-44, 10.1016/j.idairyj.2015.05.011.
2. J.T. Lejeune; Päivi J. Rajala-Schultz; Frederick J. Angulo; Unpasteurized Milk: A Continued Public Health Threat. *Clinical Infectious Diseases* **2009**, *48*, 93-100, 10.1086/595007.
3. Batavani, R.; Asri, S.; Naebzadeh, H; The effect of subclinical mastitis on milk composition in dairy cows. *Iran. J. Vet. Res.* **2007**, *8*, 205–211, .
4. Sharma, A.; Chhabra, R.; Sindhu, N. Prevalence of sub clinical mastitis in cows: Its etiology and antibiogram. Indian J. Anim. Res. 2012, 46, 348–353.
5. Sharma, N.; Maiti, S.; Sharma, K.K. Prevalence, etiology and antibiogram of microorganisms associated with Sub-clinical mastitis in buffaloes in Durg, Chhattisgarh State (India). Int. J. Dairy Sci. 2007, 2, 145–151.
6. Tiwari, J.; Babra, C.; Tiwari, H.; Williams, V.; De Wet, S.; Gibson, J.; Paxman, A.; Morgan, E.; Costantino, P.; Sunagar, R. Trends in therapeutic and prevention strategies for management of bovine mastitis: An overview. J. Vaccines Vaccin. 2013, 4, 1–11.
7. Simbarashe Katsande; Gift Matope; Masimba Ndengu; Davies M. Pfukenyi; Prevalence of mastitis in dairy cows from smallholder farms in Zimbabwe. *Onderstepoort Journal of Veterinary Research* **2013**, *80*, 523, .
8. F.M. Kivaria; J.P.T.M. Noordhuizen; A.M. Kapaga; Risk indicators associated with subclinical mastitis in smallholder dairy cows in Tanzania. *Tropical Animal Health and Production* **2004**, *36*, 581-592, 10.1023/b:trop.0000040935.87175.bb.
9. Matios Lakew; Tadele Tolosa; Worku Tigre; Prevalence and major bacterial causes of bovine mastitis in Asella, South Eastern Ethiopia. *Tropical Animal Health and Production* **2009**, *41*, 1525, 10.1007/s11250-009-9343-6.
10. Mpatswenumugabo, J.P.; Bebora, L.C.; Gitao, G.C.; Mobegi, V.; Iraguha, B.; Kamana, O.; Shumbusho, B. Prevalence of subclinical mastitis and distribution of pathogens in dairy farms of Rubavu and Nyabihu districts, Rwanda. J. Vet. Med. 2017, 2017.
11. Girma, S.; Mammo, A.; Bogele, K.; Sori, T.; Tadesse, F.; Jibat, T. Study on prevalence of bovine mastitis and its major causative agents in West Harerghe zone, Doba district, Ethiopia. J. Vet. Med. Anim. Health 2012, 4, 116–123.
12. M. Magnusson; A. Christiansson; B. Svensson; Christina Lunner Kolstrup; Effect of Different Premilking Manual Teat-Cleaning Methods on Bacterial Spores in Milk. *Journal of Dairy Science* **2006**, *89*, 3866-3875, 10.3168/jds.s0022-0302(06)72429-8.
13. S. Van Gastelen; B. Westerlaan; D.J. Houwers; F.J.C.M. Van Eerdenburg; A study on cow comfort and risk for lameness and mastitis in relation to different types of bedding materials. *Journal of Dairy Science* **2011**, *94*, 4878-4888, 10.3168/jds.2010-4019.
14. M.M.M. Vissers; F. Driehuis; M.C. Te Giffel; P. De Jong; J.M.G. Lankveld; Minimizing the Level of Butyric Acid Bacteria Spores in Farm Tank Milk. *Journal of Dairy Science* **2007**, *90*, 3278-3285, 10.3168/jds.2006-798.
15. Sudhan, N.; Sharma, N. Mastitis—An Important Production Disease of Dairy Animals; Sarva Manav Vikash Samiti: Gurgoan, India, 2010; pp. 72–88.
16. Markus Abrahmsén; Ylva Persson; Benon Mbabazi Kanyima; Renée Båge; Prevalence of subclinical mastitis in dairy farms in urban and peri-urban areas of Kampala, Uganda. *Tropical Animal Health and Production* **2014**, *46*, 99-105, 10.1007/s11250-013-0455-7.
17. O. Kerro Dego; F Tareke; Bovine mastitis in selected areas of southern Ethiopia. *Tropical Animal Health and Production* **2003**, *35*, 197-205, 10.1023/a:1023352811751.
18. E.O. Mungube; B.-A. Tenhagen; T. Kassa; F. Regassa; M.N. Kyule; Matthias Greiner; M.P.O. Baumann; Risk factors for dairy cow mastitis in the central highlands of Ethiopia. *Tropical Animal Health and Production* **2004**, *36*, 463-472, 10.1023/b:trop.0000034999.08368.f3.

19. Karimuribo, E.; Gallet, P.; Ng'umbi, N.; Matiko, M.; Massawe, L.; Mpanduji, D.; Batamuzi, E. Status and factors affectin g milk quality along the milk value chain: A case of Kilosa district, Tanzania. Livest. Res. Rural Dev. 2015, 27, 51.
20. Silvana Mattiello; Mariangela Caroprese; Crovetto Gianni Matteo; Riccardo Fortina; Andrea Martini; Mina Martini; Giulia na Parisi; Claudia Russo; Massimo Zecchini; ASPA Commission "Animal Productions in Development Cooperation Proj ects"; et al. Typical dairy products in Africa from local animal resources. *Italian Journal of Animal Science* **2018**, *17*, 740 -754, 10.1080/1828051x.2017.1401910.
21. Owusu-Kwarteng, J.; Akabanda, F.; Johansen, P.; Jespersen, L.; Nielsen, D.S. Nunu, A West African Fermented Yogurt -Like Milk Product. In Yogurt in Health and Disease Prevention; Shah, N.P., Ed.; Elsevier Academic Publisher: London, UK, 2017.
22. W H Holzapfel; Appropriate starter culture technologies for small-scale fermentation in developing countries. *Internation al Journal of Food Microbiology* **2002**, *75*, 197-212, 10.1016/s0168-1605(01)00707-3.
23. Josephsen, J.; Jespersen, L. Starter cultures and fermented products. In Handbook of Food and Beverage Fermentatio n Technology; CRC Press: Marcel Dekker, NY, USA, 2004; pp. 39–66.
