Risk Factors and Possible Strategies to Mitigate Microbiological Hazards in Milk and Dairy Products in Ethiopia: A Review

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ABSTRACT

The quality and safety of milk and dairy products are global concerns, particularly in developing countries like Ethiopia. Poor animal health and unhygienic production environments often contribute to on-farm contamination with microbiological hazards throughout the milk value-chain. Sources of contamination include milk handling equipment with unsanitary design, improper milk storage conditions, and unhygienic milk transportation. Moreover, lack of knowledge and skills for hygienic production and processing of milk and dairy products are the major concerns for the dairy industry in the country. All of these challenges contribute to microbial contamination of milk and dairy products, which increases the risk of foodborne diseases. To protect the public health, improving the safety of milk and dairy products should be prioritized through interventions targeting improvements in hygienic and sanitary production practices.

Key words: Milk, Ethiopia, contamination, hygiene, prevention

INTRODUCTION

Milk is known for its high nutritional value and has been increasingly included in human diets (FAO, 2013; Mwambete & Nakembetwa, 2015; Walstra *et al.*, 2006). However, the nutritional content of milk, together with its high water activity (aw), provides suitable conditions for growth of a multitude of spoilage and pathogenic microorganisms (FAO, 2013; Paraffin *et al.*, 2018; Velázquez-Ordoñez *et al.*, 2019). Additionally, milk produced in unhygienic environments using methods that do not follow the principles of good hygienic practices is conducive to microbial contamination (Paraffin *et al.*, 2018). This may increase the exposure of consumers to foodborne pathogens, resulting in foodborne infections. Exposure to foodborne pathogens through consumption of contaminated milk and dairy products is a global problem, which is exacerbated in developing countries (Ahmedsham *et al.*, 2018; EL-Ziney & AL-Turki, 2007). It needs to be mitigated by improving the management of environmental and personal hygiene in the dairy supply chain. The first step towards mitigation includes effective educational interventions (Ahmedsham *et al.*, 2018; Kebede *et al.*, 2019; Yodit *et al.*, 2017; Velázquez-Ordoñez *et al.*, 2019).

Milk collected from healthy cows typically has low microbial load and deemed free of pathogenic microbial contamination (FAO, 2013; SNV, 2017). Microbial contaminants are most commonly introduced into milk during the milking practice and/or at subsequent milk processing steps (Fufa *et al.*, 2019; Asaminew & Eyassu, 2011). For example, the farm environment such as dirty udder exteriors, feces, bedding, and soil in the milking environment and contaminated surfaces of milk handling equipment and utensils (unsanitary design and insufficient cleaning) contribute heavily to contamination during milking (Amanuel & Ulfina, 2018; Hayes *et al.*, 2001; Makovec & Ruegg, 2003; McKinnon & Bramley, 1990; Oladipo *et al.*, 2016; Amanuel & Haftom, 2016; Velázquez-Ordoñez *et al.*, 2019). These problems are seeable in countries like Ethiopia where there are a number of challenges in acquiring appropriate milk handling equipment and limited access to clean water (Tadele, *et al.*, 2016; Solomon *et al.*, 2013; Weldegiorgis & Gebremariam, 2019). This compounding effect deteriorates the quality, safety, and quantity of milk produced in the country, ultimately jeopardizing food security, public health, and agriculture development (Fekadu, 1995; SNV, 2008).

The objective of this paper is to provide an overview of the potential sources of microbial contamination of milk and dairy products in Ethiopian dairy supply chain and to provide information on promising mitigation procedures through a review of previously published peer-reviewed literature. Moreover, the information provided in this paper can be used to inform future interventions areas in the dairy value chain of Ethiopia.

METHODOLOGY

This paper was prepared through a comprehensive literature review by searching scientific literature databases, including Semantic Scholar, African journals online, PubMed, Directory of Open Access Journals, Europe PMC, and Science Direct. Peer-reviewed studies reporting hygienic practices and microbial quality of milk and dairy products in Ethiopia were identified and reviewed. Additionally, articles that reported risk factors associated with microbial contamination of milk and dairy products and mitigation procedures were included in the review. Between January 2020 and June 2020 six (6) databases were searched using the keywords “Ethiopia” AND (“dairy” OR “milk”) AND (“risk factors” OR “microbiological contamination” OR “prevention” OR “mitigation”) AND/OR “quality/safety”. The results of each search were filtered based on the relevance of the title and abstract. Relevant papers were also reviewed to further identify relevant literature, which was included in this review paper.

FINDINGS

Microbial contamination of milk and dairy products can originate from various sources (Oumer *et al.*, 2017). Therefore, source attribution can be challenging and difficult to determine. However, there are several risk factors that, when examined, can provide insight into the root of the microbial contamination of milk and dairy products **(Figure 1).** The factors include animal health, farm management and environmental factor, milking and milk handling practice, milk handling equipment and sanitary practices, milk storage and transport, and water source. The following discussion provides further detail on these factors and possible mitigation procedures.

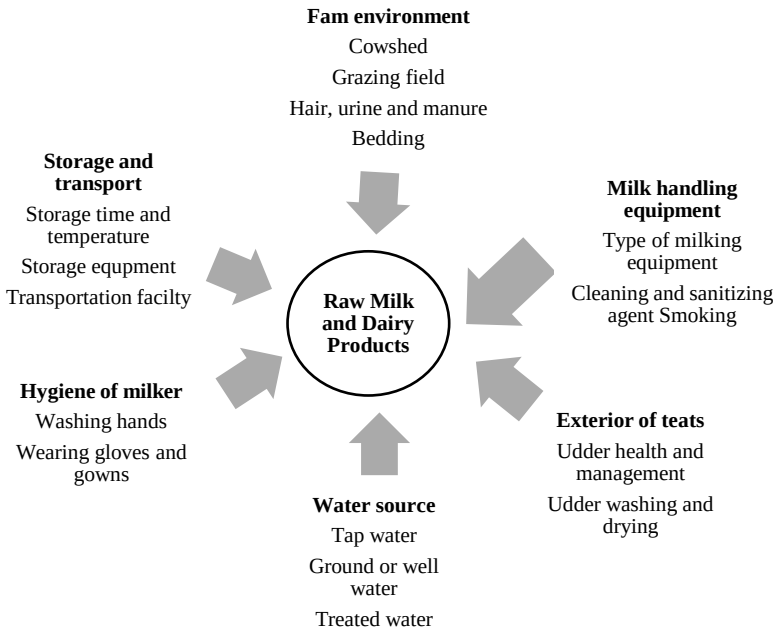

Figure 1. Factors contributing to microbial contamination of milk and dairy products

Animal Health

Animal health is an essential part of milk production as it influences the quantity, safety, and quality of milk being produced (Quinn *et al.*, 1994). Therefore, the health status of a dairy herd is the first indicator of the safety and quality of milk and dairy products. Unhealthy animals, particularly lactating cows can produce unsafe milk due to shedding of microorganisms that can cause infection in both animals and humans. Hence, poor animal health can have a negative public health impact by increasing the risk of foodborne illness (Alehegne *et al.*, 2004; Bekele & Molla, 2000; Jay, 2000; Quinn *et al.*, 1994; Radostits *et al.*, 1994). Bovine tuberculosis caused by *Mycobacterium bovis* and brucellosis caused by *Brucella* are among the major animal diseases that can impact public health through the consumption of raw milk produced by infected herds (Pedro Acha & Boris Szyfres, 2001). In addition to these two infectious diseases, mastitis is considered as one of the most concerning dairy cattle disease (Naqvi *et al.*, 2018; Tančin *et al.*, 2018). Mastitis is associated with a bacterial infection in one or more quarters of the mammary gland of dairy cows (Hamann, 2010; Pandey & Voskuil, 2011). *Staphylococcus aureus*, *Streptococcus agalactiae*, *Corynebacterium bovis*, and coliforms are the most common contagious pathogens known to cause bovine mastitis (Acha & Szyfres, 2001; Molalegn *et al.*, 2010; Dufour *et al.*, 2019; Gao *et al.*, 2017; Idriss *et al.*, 2014; Naqvi *et al.*, 2018; Schaika *et al.*, 2005; Velázquez-Ordoñez *et al.*, 2019).

Although mastitis has been a serious challenge for the Ethiopian dairy industry, it is not given due attention (Fufa *et al.*, 2019; Lore *et al.*, 2006). Studies conducted across Ethiopia reported variable prevalence of mastitis **(Table 1)** with the overall prevalence of both clinical and sub-clinical mastitis exceeding 60% (Birhanu *et al.*, 2013; Demelash *et al.*, 2005; Yien et al., 2014; Nibret *et al.*, 2012; Bayush & Ataro, 2018; Mulugeta & Wassie, 2013). Non-isolation and milking of cows infected with mastitis were identified as major sources of pathogenic microbial contaminants in milk such as *Escherichia coli*,

Streptococcus uberis, *Streptococcus dysgalactiae*, and other *Gram-positive* and *catalase-negative cocci* (Dufour *et al.*, 2019). Furthermore, failure to maintain sanitary shelter with proper ventilation and lack of regular veterinary visits for early detection and treatment of disease has exacerbated the problem and resulted in widespread mastitis in Ethiopian cattle (Nibret *et al.*, 2012). To prevent the entrance of many pathogenic bacteria into the milk chain, therefore, compliance with good milking practices is extremely important. These practices include cleaning and removal of soil particles from the teats prior to milking, using sanitary bedding material that can facilitate ease of cleaning, and removal of manure from the teats, udder and adjacent parts (FSA, 2006; ICAR, 2011; Nangamso, 2006; SNV, 2017). In general, using proper milk handling equipment, regular physical or clinical examination, culling chronically infected cows, monitoring of udder health and maintaining appropriate environment are critical animal health management and mastitis control procedures (Murphy, 1996; O'Connor, 1995; Radostits *et al.*, 2006; Velázquez-Ordoñez *et al.*, 2019; Zelalem *et al.*, 2011).

Farm Management and Environmental Factors

The production of safe milk begins with the implementation of good hygienic practices on-farm, which is an effective first step in reducing milk contamination (Barbuddhe & Swain, 2008; Carloni *et al.*, 2016; Bekele & Molla, 2000; Ramírez-Rivera *et al.*, 2019). Farm management includes preventing cows from grazing in unhygienic pasture and living in sheds that are not cleaned on a regular basis (Carloni *et al.*, 2016; Pandey & Voskuil, 2011).

Unhygienic milking environments can facilitate the spread of microorganisms (Fuentes *et al.*, 2014; Zdanowicz *et al.*, 2004). Exposure of cow's udder to environment contaminated with feces or debris is a major source of microbial contamination of milk (Fufa *et al.*, 2019; Vacheyrou *et al.*, 2011). Additionally, irregular cleaning of the milking areas and animal sheds contributes to cross-contamination of milk in household dairy farms (Carloni *et al.*, 2016). This is a major challenge in Ethiopia, as on-farm infrastructure is commonly underdeveloped. And most of the cow sheds are built using trees while a few of them are made of blocks and iron sheets (Shija, 2013).

Table 1: Prevalence of mastitis across cow breed, age, lactation and parity in Ethiopia

Cows	*Breed type*			*Lactation stage*			*Parity No. (in calves)*		*Age (years)*			*Study location*	*Reference*
	Holstein-Friesian	*Holstein-Zebu*	*Zebu*	*Early*	*Mid*	*Late*	*1-3*	*>4*	*3-5 (young)*	*6-10 (adult)*	*>10 (old)*		
Examined	53	113	17	66	67	50	142	41	-	-	-	Hawassa; SNNPR	Nibret *et al.*, 2012
Infected	17	35	4	14	17	25	32	24	-	-	-		
Prevalence	32.1	30.9	23	21.2	25.3	50	22.5	58.5	-	-	-		
Examined	-	-	-	37	74	10	23	98	22	27	72	Gambella	Yien *et al.*, 2014
Infected	-	-	-	21	41	8	13	58	9	17	47		
Prevalence	-	-	-	56.7	55.4	80	56.5	59	40.9	62.96	65		
Examined	186	259	446	214	403	357	328	315	326	399	249	SNNPR	Demelash *et al.*, 2005
Infected	105	73	138	98	104	138	37	198	77	152	111		
Prevalence	56.5	28.2	30.9	45.8	25.8	38.7	11.3	62.9	23.6	38.1	44.6		
Examined	-	-	-	64	176	-	91	305	68	174	89	Addis Ababa	Fufa *et al.*, 2019
Infected	-	-	-	32	99	-	42	168	23	97	53		
Prevalence	-	-	-	50	56.3	-	46.2	56.3	33.8	55.75	59.5		
Examined	-	349	139	94	121	134	177	137	104	155	90	Wolayita, SNNPR	Mulugeta & Wassie, 2013
Infected	-	103	15	62	4	37	21	58	11	44	48		
Prevalence	-	29.5	10.5	65.9	3.3	27.6	11.9	42.3	10.6	28.4	53.3		
Examined	-	-	-	-	-	-	202	204	197	168	63	Holeta, Oromia	Berhanu *et al.*, 2010
Infected	-	-	-	-	-	-	68	112	66	94	32		
Prevalence	-	-	-	-	-	-	37.7	54.9	33.5	56.0	49		
Examined	499	-	-	133	132	234	94	108	323	176	-	Addis Ababa	Tesfaheyw et *et al.*, 2013
Infected	373	-	-	116	87	171	43	96	210	164	-		
Prevalence	74.1	-	-	87.2	65.9	73.1	45.7	88.9	65	93.2	-		
Examined	185	-	-	67	61	88	76	140	90	27	99	Jimma, Oromia	Bayush & Ataro, 2018
Infected	126	-	-	50	32	54	51	85	58	19	59		
Prevalence	92.6	-	-	36.8	23.5	39.7	37.5	62.5	42.6	13.97	43.4		
Examined	290	-	-	94	90	106	152	137	135	107	48	Sebeta, Oromia	Yomiyu *et al.*, 2017
Infected	164	-	-	35	45	57	70	67	60	51	26		
Prevalence	56.5	-	-	37.2	50	53.8	45.8	55.1	44.4	47.66	54.2		
Examined	91	-	293	115	108	161	198	186	202	122	60	Haramaya, Oromia	Bayan Amin *et al.*, 2017
Infected	40	-	149	74	33	85	85	104	86	63	40		
Prevalence	43.9	-	56.6	64.3	30.5	52.7	42.9	58.1	42.5	51.6	66.6		
Examined	125	-	26	74	-	77	119	32	107	44	-	Ambo, Oromia	Getachew & Edilu, 2016
Infected	56	-	4	34	-	29	37	26	30	31	-		
Prevalence	47.2	-	15.4	45.9	-	37.7	31.1	81.3	28.0	75	-		
Examined	327	-	57	152	80	152	280	104	153	195	36	Harrargh e, Eastern Ethiopia	Tesfaheyw et & Gerema, 2017
Infected	170	-	29	77	49	73	135	64	48	130	21		
Prevalence	52	-	50.9	50.7	61.3	48.0	53.0	61.9	31.4	66.7	58.3		
Examined	14	-	370	130	194	60	161	77	135	167	82	Benchi Maji, Western Ethiopia	Teshome *et al.*, 2019
Infected	10	-	106	18	71	27	21	35	25	51	40		
Prevalence	71.4	-	28.6	13.8	36.6	45	13	45.5	18.5	30.5	48.8		

A study conducted by Mitiku *et al.* (2019) in Haramaya district, reported that all cowsheds (100%) included in their study were not constructed in a way that would facilitate drainage of farm waste, including animal feces and urine. The report also indicated that cowsheds did not use proper bedding materials like sand bedding for the animals to prevent dairy cow udders from becoming soiled. Similar studies revealed that 81% and 83% of the evaluated households did not use any bedding material in Jimma and Sidama Zones Respectively (Abebaw & Ephrem, 2018; Mesfin *et al*., 2015). Moreover, the floors were not hygienically cleaned rather they were commonly covered with manure, and had improper drainage systems. In another study conducted in southern part of Ethiopia Abebe *et al.* (2012) reported that 67% of the households used straw or hay as bedding material. However, such bedding materials need to be changed frequently, to prevent the transmission of pathogenic bacteria potentially present in the environment to milk (Sanaa *et al.*, 1993). Microorganisms present in bedding material can also contaminate the surface of animal udder, resulting in mastitis (Vacheyrou *et al.*, 2011). Zdanowicz *et al.* (2004) indicated that coliform counts in milk samples is reduced when cows are housed in an environment with sand bedding as compared to straw or sawdust bedding. Thus, clean and dry bedding condition is important to reduce microbial contamination of milk (Abebe *et al.*, 2012; Gurmessa, 2015; Sanaa *et al.*, 1993).

Milking is conducted inside a confined shed on a majority of smallholder dairy farms in Ethiopia, where there is a high risk of contamination through the dusty air and insects (Abebe *et al.*, 2012). Lack of sufficient space, especially in urban areas, and irregular cleaning of milking rooms and cowsheds can create suitable conditions for the growth of insects like flies that can transmit pathogens (Pandey & Voskuil, 2011). Furthermore, most of the smallholder farmers, particularly in rural areas, share a common dwelling with their animals, and the close proximity can facilitate the spread of bacteria to the milk originating from human hair, cloth and other sources (Abebe *et al.*, 2012). Betelihem and Shimels (2017), reported that 52% of the farms included in their study did not have a separate milking cowshed. In this regard, lack of comprehensive and uniform hygienic procedures to be followed by producers has posed a challenge to implement and use new procedures and research findings in the dairy sector of Ethiopia (Tesfaye, 2019; SNV, 2017; Zelalem, 2003).

In general, cleanliness of the premises and the environment can significantly reduce risk factors contributing to poor quality milk production and mastitis as it results from unhygienic conditions (Abebe *et al.*, 2012; Buncic, 2006). Hence, a proper and clean housing environment, is a pre-requisite to produce milk of acceptable quality and safety as it can significantly reduce risk factor of mastitis and other pathogenic microbes like *Listeria monocytogenes* (Abebe *et al.*, 2012; Amanuel & Ulfina, 2018; Sanaa *et al.*, 1993).

Milking and Milk Handling Practices

Milking and milk handling practices have significant effects on the quality and safety of milk and milk products (Betelihem & Shimels, 2017). Hygienic milking practices aim to prevent the transmission of zoonotic and communicable diseases through milk to consumers. Hygienic milking practices include regular cleaning and washing of animal udder and milk handling equipment before and after milking, use of separate and clean drying towels between cows, the filtering of milk after milking and avoiding the feeding of cows during milking. Good hygienic practices can prevent the transmission of zoonotic diseases by reducing the risk of milk contamination with pathogenic bacteria (Barbuddhe & Swain, 2008; Lore *et al.*, 2006; Pandey & Voskuil, 2011).

Poor cleaning and disinfection of teat has repeatedly been identified as a risk factor for contamination of raw milk by certain pathogens like, *Listeria monocytogenes* (Sanaa *et al.*, 1993). In 2019, Fufa *et al.* (2019) reported that udder washing before milking is not widely practiced by Ethiopian dairy farmers. Of the 70 participants surveyed in their study, 26% did not wash udders prior to milking and only 30% of them used separate drying towels or cloths between milked cows to dry udders after washing. This data is based on selected sub-cities of the country's capital, Addis Ababa, and it is the authors' belief that this issue is magnified more in rural parts of the country where farmers typically do not avoid milking cows that show signs of infections, and where improper hand washing and handling of milk is common. In similar studies conducted in the cities of Gonder, Harrarghe and Dangila, 72, 99, and 94% of the participants, respectively, were not regularly washing cows' udders and teats before and after milking cows, unless the udder was contaminated with manure (Bekele *et al.*, 2015; Mitiku *et al.*, 2019; Betelihem & Shimels, 2017). Other studies also revealed that among the participants who practiced regular washing of cows' udders, more than 80% failed to dry the washed udder using a dry and clean towel or a cloth (Abebe *et al.*, 2012; Bayan Amin *et al.*, 2017; Bekele *et al.*, 2015; Gezu *et al.*, 2015).

Ethiopian farmers may use a myriad of techniques to remove dirt from udders, including allowing a calf to suckle prior to milking or using a dry cloth to remove dirt from the teats and udder of the animal. On the other hand, covering of the udder by using dung or mud is practiced in some parts of the country to prevent calves from suckling while the cows are grazing. When calves are given the teats before milking to suckle, the unwashed teats and saliva left from calves can be sources of bacterial contamination during milking. Failure to thoroughly clean and dry the udder and teats is a common source of coliforms in milk (Alehegne *et al.*, 2004; Pandey & Voskuil, 2011). The above-outlined poor practices increase the risk for mastitis or similar diseases, which can result in a significant loss in both quantity and quality of milk produced (Alehegne *et al.*, 2004).

Hand milking is a common practice across the country and can contribute to milk contamination by the milker. In most parts of the country, all cows in a given farm are milked by a single milker (Zelalem *et al.*, 2011; Alehegne *et al.*, 2004). As the milkers' moves from one cow to the next, without washing and disinfecting their hands, they can potentially transfer pathogenic microorganisms between animals in the herd. Furthermore, if the milker is sick, s/he can transmit disease through milk handling (Abebe *et al.*, 2012; Mitiku *et al.*, 2019). Betelihem and Shimels (2017) reported that out of 60 randomly selected dairy farmers included in their study, 19 (32%) did not practice hand-washing prior to milking. In many instances, where hand-washing practices were in place, only water was used to wash hands (Mitiku *et al.*, 2019). This is not necessarily sufficient for the removal of all bacteria from hands and can compromise milk quality and safety (Pandey & Voskuil, 2011; Zelalem *et al.*, 2011). Hence, proper handwashing both before and after milking should be practiced among dairy farmers by using water and soap, which can significantly reduce the microbial load on hands and therefore reduce the risk of milk contamination (Sanaa *et al.*, 1993; Eyasu *et al.*, 2015).

Filtering of milk before further processing is an important step followed to avoid exposure of milk to physical hazards (Pandey & Voskuil, 2011; SNV, 2017). Tadele *et al.* (2016), reported that 80, 15, and 5% of the participants use bare hands, sticks, and spoons, respectively, to remove extraneous material from milk. It is evident that the use of filters may be the appropriate solution to minimize cross-contamination and prevent physical hazards (e.g., hair, soil, jewels, and other similar extraneous materials) from entering into the milk. Filtering of milk can result in good quality reducing physical hazards; and ensuring consumer's health (Schaika *et al.*, 2005). Moreover, inappropriate animal

husbandry practices like feeding roughage at the time of milking should be avoided, as the dust and/or smell easily contaminates the milk (Pandey & Voskuil, 2011).

In the dairy sector of developing countries, women have an important role, particularly in milking and milk handling practices (FAO, 2011; Berhanu *et al.*, 2006). In most parts of Ethiopia, particularly in rural areas, activities related to animal husbandry and milk production are responsibilities of women (Mushir & Mulugeta, 2012; Amanuel & Ulfina, 2011; Mitiku *et al.*, 2019; Amanuel & Haftom, 2016). Therefore, along with the implementation of hygienic milk handling procedures, empowering women with necessary skills and knowledge is one intervention area that has a potential to reduce the risk of milk contamination (FAO/IDF, 2011). In general, milk production and handling practices in Ethiopia are not carried out hygienically. Hence, in order to raise awareness among the dairy value chain actors and design effective and acceptable interventions to instigate behavior change in the milk production and handling, it is crucial to understand the local context of milk production, handling, and processing (Kebede *et al.*, 2019; Koome, 2016; Lore *et al.*, 2006)

Milk Handling Equipment and Water Source Used for Sanitation

Equipment used for milk handling, storage, and transportation has an effect on the safety and quality of milk and is a major source of microbial contamination (FSA, 2006; SNV, 2017). Microbiological contamination can result from equipment surfaces, especially joints, open seams, and dents that are difficult to clean properly and can harbor microorganisms such as spore-forming bacteria and *Listeria monocytogenes*, and can lead to microbial persistence within milk processing facilities (Chmielewski & Frank, 2004; Pauline & Karin, 2006; Simo˜es *et al.*, 2010; Vissers & Driehuis, 2008).

In Ethiopia, the majority of the farmers use plastic containers, clay pots, and bottle gourds to carry milk, which are difficult to thoroughly clean due to their shape and narrow opening (Abebe *et al.*, 2012; Aleme *et al.*, 2018; Habtamu & Adugnaw, 2018; Felleke, 2003). Donkor *et al.* (2007), indicated that the use of plastic milk containers was found to be one of the potential risk factor associated with coliform contamination in milk. The use of plastics should be avoided because the material may be easily scratched and that surface can serve as source of persistent contamination and cross-contamination. Hence, the surface of the materials should be smooth, with minimal joints or open seams, and should be free from dents (Buncic, 2006; Pandey & Voskuil, 2011). Stainless steel is recommended to use, as it is easy to clean, durable, does not absorb smells, is not corrosive and can resists detergents (Johanna *et al.*, 2003). However, small scale dairy farmers may not be able to afford stainless steel containers as they are a bit expensive, in such cases it is highly recommended to use other available milking and transportation containers like Mazzican (MTS), which is introduced by SNV. Mazzican is a durable 10 litre food-grade plastic container that has a wide opening and transparent plastic, which makes it easy to pour milk into it and enables the farmers to detect dirt easily (SNV, 2018). Therefore, milk handlers need to pay particular attention to the type of milk handling equipment used (Simo˜es *et al.*, 2010).

In Ethiopia, the main sources of water for sanitary activities associated with milk handling equipment include rivers or spring water, ponds, rain water, ground or well water and tap water (Abebe *et al.*, 2013; Mitiku *et al.*, 2019; Mesfin *et al.*, 2015). Water from these sources is typically used without further treatment (Fufa *et al.*, 2019; Aleme *et al.*, 2018; Dessalegn, 2017; Mitiku *et al.*, 2019; Shija, 2013). Furthermore, the use of poor-quality contaminated tap water can also lead to introduction of pathogenic bacteria into the milk production chain (Amanuel & Ulfina, 2018; Oladipo *et al.*, 2016). Eyasu

et al. (2015) and Sanaa *et al.* (1993) reported that the use of detergent together with clean and warm water reduced the risk of contamination of milk with *Staphylococcus aureus* and *Listeria monocytogenes*. Efficacy, safety and ease of removal are the selection criteria's for detergents and disinfectants to be used for cleaning and disinfection of milk handling equipment (Dosti *et al.*, 2005; Simo˜es *et al.*, 2010).

Smoking of milking and milk handling equipment after washing with tap water is well practiced in most parts of the country (Tadele *et al.*, 2016; Aleme *et al.*, 2018; Mitiku *et al.*, 2019; Tsadkan & Gurja, 2018). Mogessie (1996), reported smoking of milk handling equipment can influence the growth of pathogenic and spoilage microorganisms. The study indicated that smoking has an inhibitory effect on *Listeria monocytogenes*. It is evident that smoking can also contribute to milk quality by improving flavor, appearance and texture of fermented dairy products.

In conclusion, to reduce the risk of microbial contamination of milk during and after milking, milk handling equipment should be kept hygienic and washed regularly with clean tap water and then thoroughly scrubbed with warm water and detergent. In addition, it must be brushed properly with clean bristles used only for food contact surfaces, to reduce the level of contamination and minimize food safety risks (Fufa *et al.*, 2019; Kebede *et al.*, 2019; Lore *et al.*, 2006). Finally, after rinsing with clean water, the container should be left for drying turned upside down on a drying rack aiding fast drying and reducing exposure to environmental contaminants (Pandey & Voskuil, 2011; Yien, 2019; SNV, 2017).

Milk Storage, Transport and Cold chain

Poor storage and transportation conditions can further facilitate the contamination of milk from milk handing equipment. Raw milk can only be kept for hours without storage at an appropriate temperature (4°C) before it deteriorates in both quality and safety (SNV, 2008). Therefore, it must be stored and kept cool using proper refrigeration within two hours after milking, it maintains nearly its original quality and remains fresh for a reasonably longer time until processing and consumption (Pauline & Karin, 2006; SNV, 2008). However, such storage facilities are not readily available in Ethiopia, particularly in rural areas and cooling systems are not feasible due to lack of the required dairy infrastructure and unstable power supply (Mitiku *et al.*, 2019; O'Connell *et al.*, 2016). When available, there is a high cost associated with facilities maintaining refrigerators for small smallholder producers (Abebe *et al.*, 2013). Hence, the raw milk is easily spoiled, which results in significant losses in milk production. According to Forsbäck *et al.* (2011), milk quality, in terms of protein and fat deteriorates much faster during storage, owing to increased somatic cell count (SCC) and mastitis pathogens (e.g., other bacteria, mainly *psychrotrophs*).

Means of transportation used for the delivery of milk can also influence the quality and safety of milk. Animal-drawn carts, motor bicycles, three-wheel drive vehicles (Bajaj), four-wheel-drive vehicles, or public transportation are among the methods used as a means to deliver milk to collection centers or selling points by dairy farmers in Ethiopia (SNV, 2017). These forms of transportation are not appropriate, especially when important hygiene and food-safety considerations are not taken into account. Almost all means of transportation, particularly public transportation, are not safe as they do not provide facilities for cooling the milk (Wayua *et al.*, 2012).

The time it takes to transport or deliver milk to collection centers is another factor that affects its quality and safety. According to Eyasu *et al.* (2015), samples from dairy farmers that had more than a 30 min travel time to the collection center had a 5.6 times higher risk of contamination with *Staphylococcus aureus* when compared to farmers that had less than 30 min of travel time to the collection centers. The study also indicated that for every one-liter increase in milk delivered, the probability of contamination

with *Staphylococcus aureus* increased by 4%. The establishment of milk collection centers with cooling facilities near to the dairy farmers can be seen as one of the ways to minimize the milk waste due to improper storage and transportation conditions (Sintayehu *et al.*, 2013). In rural areas of the country, placing the milk in containers at cool (windy) places or in a cool water and electrical or solar operating bulk cooling tanks can be used to cool milk at the farm level (Alehegne *et al.*, 2004; Amanuel & Ulfina, 2018). These alternatives allow harvested milk to be stored longer and maintain its quality and safety. Even though not well known or practiced, the use of preservatives like lacto-peroxidase has been recently used to prolong milk shelf life (Pandey & Voskuil, 2011; SNV, 2017). In conclusion, milk should be cooled to a suitable temperature (4°C) and transported by means that maintain its quality and safety.

Hygienic Conditions at Market places

Milk and dairy products are marketed in formal and informal marketing systems (Mohamed *et al.*, 2004; Weldegiorgis & Gebremariam, 2019). In Ethiopia, the informal milk marketing system is dominant (Land O'Lakes, 2010). Ninety percent of the milk produced by smallholders is marketed in an informal marketing system; and only the remaining 10% is delivered to the formal market (SNV, 2008).

Informal marketing systems are widely observed in traditional open markets and at the household level, in which limitations on infrastructure, proper packaging, storage and transportation equipment are present (Aleme *et al.*, 2018; Eyassu & Asaminew, 2014). Market access in a pastoral production system is particularly limited, which has led to a majority of the produced milk to be sold through informal market settings (Kebede *et al.*, 2019; Dessalegn, 2017; Tsehay, 2001). The hygienic conditions of the informal markets are not monitored or sustainably maintained (SNV, 2008; Mohamed *et al.*, 2003; Kebede *et al.*, 2019; Tsehay, 2001; Welearegay *et al.*, 2012; Tsadkan & Gurja, 2018). According to the Central Statistics Agency (CSA), of the total urban milk production, 73% is sold, 10% is left for household consumption, 9.4% goes to calves and 7.6% is processed into butter and cheese (CSA, 2011).

Recently, efforts have been made to establish and expand dairy cooperatives in different parts of the country which is important for increasing and improving the formal milk marketing systems; leading to an improved infrastructure and frequent product quality monitoring (Tesfaye, 2019). According to Berhane and Workneh (2003), dairy marketing cooperatives could provide farmers with continuous milk outlets and easy access to essential inputs such as artificial insemination, veterinary services and formulated feeds. Thus, dairy cooperatives are needed to start a positive series of development in the milk production sub-sector and further improve the existing dairy cooperatives around the country.

Future perspectives

During the past few decades, many studies have been carried out showing the prevalence and risk factors associated with pathogenic and spoilage microorganisms in milk and dairy products in Ethiopia (Abdi *et al.*, 2020; Nibret *et al.*, 2012; Bayush & Ataro, 2018; Tesfaheywet & Gerema, 2017; Tesfaheywet *et al.*, 2013). However, the published results so far in this area are limited to the district or regional level. Thus, a more comprehensive study is required to show the overall prevalence and risk of contamination of milk across the country. To develop a more complete framework for the prevention and reduction of contamination of milk and dairy products, future studies should consider the development of hygienic practices and procedures guidelines based on identified sources of contamination. Moreover, future

studies should be supported with experiments to evaluate the efficacy of specific intervention that had not been well researched.

CONCLUSION

Milk contaminated with foodborne pathogens poses a threat to human health. The contamination may result from infected or sick animals, unhygienic conditions and practices in milking and milk handling, unhygienic milking equipment and poor quality of water. The safety and quality of milk is highly affected by unhygienic practices in different stages of milk production. Reduced quantity and quality of milk production has been a challenge for the dairy sector in Ethiopia, resulting in a significant economic and social impact. The elimination of pathogenic and spoilage microorganisms from human carriers and environmental sources is critical for the success and the production of high quality and safe milk. Improvement in animal husbandry and farm management, increasing the awareness of hygienic milking and milk handling practices among the dairy value chain actors, and the development and implementation of hygienic milk production procedures are identified as priority areas for intervention to improve the quality and safety of milk and dairy products produced in Ethiopia.

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