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Milk Post-harvest Losses, its Causes and Mitigation Strategies along the Dairy Value Chain of Selected Milk Sheds of Ethiopia

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ABSTRACT

Background: The lack of suitable markets and spoilage are the main causes of post-harvest losses of milk and dairy products along the supply chain. Milk loss can be seen in economic, qualitative, quantitative and nutritional terms. Reduction in amount is referred to as a quantitative loss, but an economic loss is decrease in the food's value as a result of physical loss.

Methods: The study was conducted at Addis Ababa-Selale, Ambo-Waliso and Adama-Asella milk sheds with the objective to investigate milk postharvest losses, their causes and mitigation strategies along the milk sheds. Depending on their potential for dairy production, three milk sheds were purposively selected, whereas households selected randomly and proportional to their size. A total of 296 smallholder dairy producers from the districts, 16 milk collectors, 3 dairy plant processors, 35 milk retailers and 115 milk consumers were selected for semi structured interviews. The collected data were analyzed using Statistical Package for Social Sciences (SPSS) version 24 software.

Result: The majority of the respondents (92.9%) reported that the common milking equipment used for milking was plastic buckets. The total milk postharvest loss among the milk sheds were (40.5%) in Addis Ababa-Selale, (17.33%) in Ambo-Waliso and (7.24%) in Adama-Asella. As mitigation strategies for post-harvest losses, refrigerators, keeping milk in cold water and clean milk storage were practiced in the area by (1.3%), (21.2%) and (73%) of the respondents, respectively. In conclusions, total milk post-harvest loss was 21.6% in the study milk sheds. Therefore, mitigation strategies and further intervention should be implemented at each stage of milk postharvest loss, focusing on hygienic milk handling, provision of solar based refrigerators, clean milk storage and milking equipment in the study milk sheds.

Key words: Causes, Dairy value chain, Milk postharvest losses, Milk sheds, Mitigation strategies.

INTRODUCTION

The total annual milk production in Ethiopia is 7.123 billion liters, where cows' milk production (4.692 billion liters) takes the lion's share. The average daily milk yield is 1.48 liters per cow per day and the average lactation length is estimated to be seven months (CSA, 2021). Milk loss refers to the unavailability or loss of milk that should be explicitly observable in economic, qualitative, quantitative and nutritional terms. Economic loss refers to a decrease in the monetary value of food as a result of physical loss, while quantitative loss is a decrease in amount. Qualitative loss is typically based on subjective decisions (damage or spoilage) and nutritional losses are described as a decrease in the amount of a milk constituent (Ayo *et al*., 2017).

The major causes of postharvest losses and quality deterioration of milk include contamination at milking and further handling, coupled with storage time and inappropriate temperatures, deliberate adulteration of milk, inefficient processing technologies and inadequate product outlets. Postharvest management determines food quality and safety, competitiveness in the market and the profits earned by producers. In most developing countries, postharvest management of milk is far from satisfactory (Brasesco *et al*., 2019).

According to Azeze and Haji (2016) report, different practices have been performed by households to mitigate postharvest losses of milk. Among the mechanisms used to reduce post-harvest losses are smoking of milk handling equipment with various plant materials and traditional milk processing. Similarly, food availability could be increased by reducing postharvest losses without further exploitation of resources. Mitigation of post-harvest losses is seen as a possible means of increasing food availability and nutritional status in countries experiencing high food losses like Ethiopia (Brian *et al*., 2020).

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Post-harvest milk losses have a significant effect on household income, *per capita* milk consumption and the overall health of the economy. Low levels of technology are being used in the conventional milk production system to prevent microbial contamination and spread. Additionally, milk and dairy product distribution facilities are not designed to assist with proper product handling and storage in an appropriate state prior to sale. Generally, demand for milk and its byproducts have significantly increased due to increases in household income, urbanization and population. Several researchers across the country have made efforts; these efforts do not adequately reflect the current circumstances. Milk postharvest losses are dynamic along the dairy value chain and poorly measured in terms of monetary value and *per capita* milk consumption and the magnitude of milk postharvest losses has not been accurately quantified in Ethiopia. Hence, it is required to identify the root causes of milk post-harvest losses along the milk value chain. Mitigation strategies and relevant actor based interventions should be suggested to boost milk supply and benefit actors along the dairy value chain. Therefore, the current study was initiated to quantify milk postharvest losses, their causes and mitigation strategies in the selected milk sheds of Ethiopia.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Addis Ababa-Selale, Ambo-Waliso and Adama-Asella milk sheds from January 1, 2022 to February 28, 2022. The South West Shoa Zone (Waliso) is found on the main Jima road and is situated around 114 kilometers from the capital city of Addis Ababa, Ethiopia. Three districts (Ejere, Waliso and Sebeta Awass) were specifically selected for the study based on their potential for dairy production. Ambo is situated at latitude of 8°59′ N, a longitude of 37°51′ E and an elevation of 8.983°N and 37.850°E. The South West Shoa Zone is located between 1850 and 2800 meters above sea level and its average annual rainfall is 1600 mm, with minimum and maximum temperatures of 15°C and 24°C, respectively.

The East Shoa and Arsi Zone is the 200 km long milk shed where the Adama-Asella milk shed is found. Asella town, which is 175 kilometers to the south-east of Addis Ababa, serves as the capital city of the Arsi zone. It is situated between 38°41′ and 40°44′ E longitude and 6°79′ and 8°49′ N latitude. With a total area of 2,118,675 hectares, it is made up of 27.5 per cent mid-altitude, 29.1 per cent lowland and 39.7 per cent highland. The region is 500 meters above sea level (Awash and Wabe valleys) to 4245 meters above sea level (Mount Kaka). The annual temperature ranges from 10°C to 25°C. The amount and distribution of the annual average rainfall, which ranges between 901 mm and 1200 mm, are subject to some regional and temporal variations (AZADPMA, 2012).

Selale is located 114 kilometers north of Addis Ababa, in the Oromia Regional State. In terms of both the number of milking cows and the potential volume of raw milk production, this milk shed is the biggest in the Central Highlands of the country. North Shoa receives 1200 mm of rain annually and is situated at 9°48′N latitude, 38°44′E longitude and an elevation of between 2,738 and 2,782 meters above sea level. The annual temperature varies between 6°C and 21°C.

Sampling size and household selection

The study was conducted at Addis Ababa-Selale, Ambo-Waliso and Adama-Asella milk sheds. Depending on their potential for dairy production, three milk sheds were selected purposively and households were selected randomly and proportional to their size. A total of 296 smallholder dairy producers from three milk sheds, 16 milk collectors, 3 dairy plant processors, 35 milk retailers and 115 milk consumers were selected for semi structured interviews. Number of households were selected based on proportional sampling techniques. Milk producers who supply milk to milk collectors, processors, retailers and consumers in the districts and have two or more crossbred milking cows with blood levels above 50% were selected from each selected district. The sample size was calculated using Yamane's formula (1967) for smallholder dairy producers and the actors were based on their availability. Basically, a sample size was determined using 95 per cent confidence intervals and 0.05 level of accuracy variability. There were 1143 target populations selected from the three major milk sheds that have two or more crossbred milking cows.

$$n = \frac{N}{1 + N\,(e)^2}\,, n = \frac{1143}{1 + 1143\,(0.05)^2} = 296$$

Where,

n = Denotes the sample size.

N = Total population (number of households that have two or more crossbred milking cows).

e = Level of precision, sometimes called sampling error, is 5% (0.05).

1 = Designates the probability of the event occurring.

Data source and methods of data collection

In the study of milk sheds, semi structured questionnaires were used to gather information on miking, milk handling, milk transportation, clean milk storage utensils, and milk losses at producers, collectors, processors, retailers, and consumers along the dairy value chain. Milk postharvest losses from spoilage, spillage and milk forced to consume, as well as milk rejected or lost throughout the value chain, were gathered and recorded. Milk postharvest losses were assessed in two seasons: low milk production (dry, high demand season) and high milk production (wet, low demand season) to determine how milk and milk losses differ between seasons. Seasonal assessments were conducted since milk was more readily accessible and cheaper during the wet season. Because they have a considerable impact on milk price and demand, which leads to milk rejection, major holidays and fasting seasons were taken into consideration.

The total milk postharvest losses, in terms of monetary value, at the study milk sheds and the national level were calculated by multiplying the total milk postharvest losses with the current price.

To determine milk postharvest losses, there are two methods that were employed (Hodges *et al*., 2011). The first method involves tracing a particular milk commodity from production to consumption and calculating actual losses by measuring the quantity of milk and quality losses along the value chain at each stage. The second approach to quantifying food losses relies on questionnaire responses from value-chain actors who have actually experienced food losses. Both methods have been used, through semi structured questionnaires for those involved in the milk value chain, on which they register the actual milk loss at each stage and through interviews with those who had experience with milk loss in the study milk sheds.

Data analysis

The collected data on milk postharvest losses, their causes and mitigation strategies were analyzed using Statistical Package for Social Sciences (SPSS) version 24 software. Descriptive statistics such as total average, graph, tables, frequency and percentage were used to summarize the results. The total milk postharvest losses were the sum of all the milk losses that occurred at each stage of the market chain. The significance difference was reported as a p-value ($P \leq 0.05$).

RESULTS AND DISCUSSION

Causes of milk postharvest losses and spoilage along the milk sheds and market chain

In study of milk sheds, improper milk handling (28.4%), spoilage (20.3%), lack of milk marketing (22.6%), lack of cooling facilities (10.8%), lack of transportation (16.9%) and lack of roads (1%) are the most likely causes of postharvest losses (Table 1). The current results revealed that post-harvest losses of milk was significantly ($P<0.05$) different across the study of milk sheds.

Inappropriate milk handling was identified as the primary reason for milk postharvest losses by the majority of respondents (28.4%), while spoilage and lack of market access were reported by 22.6% and 20.3%, respectively. In contrast to this, Tsadkan and Amaniel (2016) reported that inadequate milk management procedures were the primary causes of milk postharvest losses (78.7%) in the Mekelle Milk Shed. Furthermore, the proportion of inefficient milk handling in the current study was lower than the findings of Kassahun *et al*.(2014), who reported that inefficient milk handling was (31.25%) in the Ada'a district. The majority of milking equipment was plastic buckets (92.9%), followed by stainless steel (4.7%) and iron buckets (2.4%). The results revealed that the majority of respondents used plastic buckets for milking, which is in line with the findings (89%) of Tsadkan and Amaniel (2016), who reported that the respondents used plastic buckets for milking in Adigudom, Merebmiet, Hager Selam, Wukro and Debri of the Mekelle Milk Shed. The current results of plastic buckets were in disagreement with the findings of Azeze and Haji (2016), who claimed that plastic buckets of milking were 35% in the districts of Dilla, Hager Selam, Dale and Hawassa districts. This difference might be due to lack of information about hygienic milk handling practices such as milking, milk handling, storage equipment and transportation, which have a bigger impact on milk's shelf life and make milk postharvest losses easier. Poor infrastructure and lack of adequate postharvest management facilities require the government to forge private and public investment partnerships to upgrade infrastructure and postharvest management facilities (Brian *et al*., 2020). To minimize the root cause of milk postharvest losses along the study milk sheds, it is required to improve hygienic handling of milk, milking storage, milking equipment, provision of solar based refrigerators or regular electricity power supply along the value chain in the study of milk sheds.

Table 1: Causes of milk postharvest losses and spoilage along the value chain.

Cause of MPHL	Causes of milk postharvest losses along the three milk sheds								
	Ambo-waliso		A/A-selale		Adama-asella		Total average		P-value
	N=57	%	N=110	%	N=129	%	N=296	%	
Poor milk handling	13	22.8	31	28.2	40	31	84	28.4	.000***
Spoilage problems	18	31.6	19	17.3	30	23.3	67	22.6	.000***
Lack of market	7	12.3	25	22.7	28	21.7	60	20.3	.000***
Lack of cooling F.	3	5.3	18	16.4	11	8.5	32	10.8	.000***
Lack of Trans.	8	14	17	15.5	25	19.4	50	16.9	.000***
Lack of road	1	1.8	2	1.8	-	-	3	1	.000***
Milking equipment									
Plastic bucket	44	77.2	83	75.5	116	89.9	275	92.9	.008**
Stainless steel	8	14	15	13.6	7	5.4	14	4.7	.062NS
Iron bucket	5	8.8	12	10.9	6	4.7	7	2.4	.050*

A/A-Addis Ababa, *-Significant, **-Very Significant, ***-Strongly Significant, NS-Not Significant.

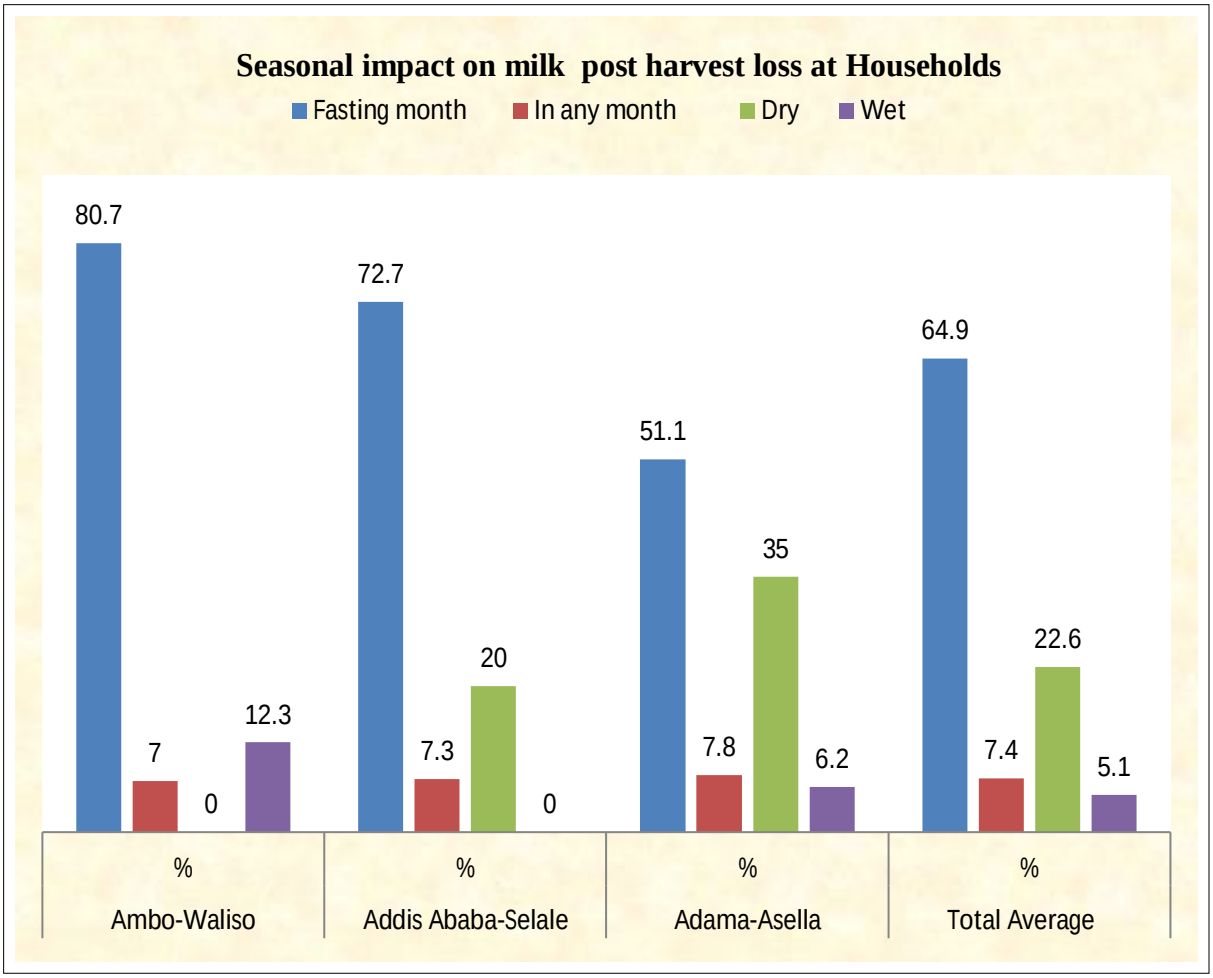
The seasonal impact on milk postharvest losses along the milk sheds and market chain

In the current study, the majority of respondents (64.9%) claimed that milk postharvest losses in the study milk sheds during the months of fasting (Graph 1). In the current study, milk lost during the wet season was in disagreement with the finding of FAO (2005), which reported that the majority (42.8%) of respondents' milk lost due to the wet season in Uganda.

The season has a big impact on raw milk post-harvest losses and milk prices. The majority of respondents (22.6%) reported that postharvest losses of milk occurred in the dry season. Fasting and the dry season were the two elements that had the biggest impact on milk postharvest losses in the study milk sheds. The volume of postharvest milk losses varies by season and the level of infrastructure development. According to FAO (2005), report forced consumption of milk is usually associated with the rainy season, when milk production peaks and market outlets for milk are limited. During the dry season, it may be reasonably assumed that most of the quantified farm losses were due to spillage and spoilage in Tanzania.

Estimated Milk Post-Harvest Losses along the milk sheds and market Chain

Annual milk production in the study milk sheds was 1,861,110 liters at Addis Ababa-Selale, Ambo-Waliso and Adama-Asella milk sheds. Out of the total annual milk production throughout the milk shed, 632,777.5 liters of milk were lost across the study milk sheds. The amounts of milk that were forced to be consumed due to lack of market access at Addis Ababa-Selale, Adama-Asela and Ambo-Waliso milk sheds were 16.39%, 3.12% and 1.68%, respectively (Table 2). The total milk postharvest losses at Addis Ababa-Selale, Ambo-Waliso and Adama-Asela were 40.5%, 17.33% and 7.24%, respectively. Thus, the current results showed that among the milk sheds, Ambo-Waliso and Addis Ababa-Selale had the largest milk postharvest losses. The average percentage of milk that was lost at the household level and collection points were 7.78% and 3.72%, respectively. The total average postharvest loss of milk was 21.6% in the study of milk sheds. The current findings revealed that the anticipated postharvest losses of milk, forced to be consumed, collectors and consumers,



Graph 1: Seasonal impact of milk postharvest losses in the study milk shed at households.

Table 2: Estimated of milk post-harvest losses along the dairy value chain.

Along value chain	Addis ababa-selale		Adama-asella		Ambo-waliso		Total average		
	Sum (L)	%	Sum (L)	%	Sum (L)	%	Sum (L)	%	P-value
Annual milk production (L)	628,605	0.71	640500	0.15	592005	0.17	1,861,110	0.34	0.000***
Total loss of milk (L)	446,309.55	-	96,075	-	100640.9	-	632777.4	-	
Price of milk AVC(Dollar)	0.808043195	-	1.042636	-	0.917892	-	0.89555	-	
Monetary value (Dollar)	360,637.39	-	100,350	-	92,377.47	-	566,684		
Milk postharvest loss									
Milk forced to consume(L)	1803	16.39	403	3.12	96	1.68	2302	7.78	0.000***
Milk rejected from P-Col (L	956	8.69	0	0	129	2.26	1085	3.67	0.000***
Milk rejected at collectors(L)	819	7.45	115	0.89	166	2.91	1100	3.72	0.205 NS
Milk rejected at processors(L)	480	4.36	125	0.97	100	1.75	705	2.38	0.557 NS
Milk rejected at retailers(L)	236	2.15	203	1.57	119	2.09	558	1.89	0.857 NS
Milk rejected at consumers(L)	156	1.42	89	0.69	378	6.63	623	2.11	0.000***
Total milk postharvest loss	4450	40.46	935	7.24	988	17.32	6373	21.55	0.431 NS

**: Significantly significant across all rows; NS: Not significant, Mean = Percentage, L = Liter of milk, P-Col = Producers to collectors.

were significantly ($P<0.05$) different across the study milk sheds.

The current results showed that the total milk postharvest loss at farm level was in disagreement with the results of FAO (2005), which reported that the total milk postharvest loss at farm level was estimated to be 6.5% of the milk available in Tanzania. The current findings showed that the total milk post-harvest losses in Addis Ababa-Selale concur with the findings of Tadesse *et al*. (2015), who reported that the milk postharvest losses occurring at the cooperative/union stage was 39% identified as loss hotspots in the dairy value chain in Ejere and Wolmera districts.

According to Azeze and Haji (2016) findings, milk postharvest losses from milking to consumption phases in the Hawassa milk shed was 40% higher than in the current study at Addis Ababa-Selale milk shed. The current findings showed that the total milk postharvest loss along the milk shed was higher than the results of FAO (2011), which reported that the estimated postharvest losses of milk and distribution in the dairy value chain were 20% and 1% in Sub-Saharan Africa and in Europe and North America, respectively.

The current results showed that, the milk rejected at collectors which is consistent with the results of Kassahun *et al*. (2014), who reported that the milk postharvest losses at collectors were of 3.8% in the Ada'a district. This loss might be occurred due to lack of mitigation strategies and regulations for policy implementation, which are crucial to mitigating postharvest losses of milk in the study milk sheds. To reduce estimated milk postharvest losses along the market chain and increase availability of milk for market, mitigation strategies such as hygienic milk handling, the provision of refrigerators or regular electric power supply, regular milk collectors and keeping milk in cold water, clean milk storage and milking equipment should be implemented in the study of milk sheds.

Mitigation strategies of milk post-harvest losses along milk sheds and market chain

In the study milk sheds, refrigerators (1.3%), keeping in cold water (21.2%) and clean storage equipment (73%) reported by the respondents as mitigation solutions for milk postharvest losses in the study milk sheds. The percentage

Table 3: Mitigation strategies for milk post-harvest losses along the dairy value chain.

Mitigation parameters	Mitigation strategies of milk postharvest losses along the three milk shed								
	Ambo-waliso		A/A-selale		Adama-asella		Over all mean		
	N=57	%	N=110	%	N=129	%	N=296	%	P-value
Refrigerator's	1	1.8	3	2.7	-	-	4	1.3	0.000***
Electric power supply	10	17.5	3	2.7	-	-	14	4.7	0.000**
Keeping in cold water	12	21.1	23	21.8	28	21.7	63	21.2	0.000***
Clean storage equipment	34	59.6	83	75.5	99	76.7	216	73.0	0.000***
Transportation of milk									
Bicycle	8	14	3	2.7	5	3.9	16	5.4	0.002***
By car	11	19.3	10	9.1	1	0.8	22	7.4	0.000***
On foot	38	66.7	81	73.6	8	6.2	127	42.9	0.0001***
Horse	-	-	6	5.5	115	89.1	121	40.9	0.168NS
Donkey	-	-	10	9.1	-	-	10	3.4	0.000***

A/A-Addis Ababa, *-Significance difference, **-Very significant, ***-Highly significant, NS-Non-significant.

of raw milk transported varied between milk sheds and modes of transportation, including bicycle (5.4%), car (7.4%), foot (42.9%), horse (40.9%) and donkey (3.4%) (Table 3). The greatest total average of respondents transporting raw milk on foot (42.9%), followed by horses (40.9%).The current results revealed that mitigation parameters like refrigerators, electric supply, keeping in cold water and clean storage equipments, were significantly ($P<0.05$) different across the study of milk sheds.

The current results showed that only (1.3%) of respondents were used refrigerators as a cooling device. While the majority of respondents (98.7%) did not have a cooling machine for milk storage, the importance of cooling machines were stressed at both the farmer's dairy cooperative and respondent levels. Refrigerators are more effective than other methods at reducing milk postharvest losses. The majority of respondents did not use cooling devices (refrigerators) as mitigation strategies, which is slightly consistent with the finding of Tadesse *et al*. (2015), who reported that smallholder dairy producers were 95% did not use cooling devices for milk storage in Ejere and Wolmera districts.

On the other hands in the current study, the milk postharvest loss is increased by a number of factors, such as absence of formal market, lack of refrigerators, lack of electricity and improper milk storage practices. The current results showed that, the majority of respondents were used milk transportation on foot, was consistent with the findings of Tadesse *et al.* (2015), who reported that the majority of peri-urban based farmers transported milk by human labor, which caused delays in reaching collection points, physical losses and quality losses due to exposure to sun heat, as well as microbial developments in Ejere and Wolmera districts of Ethiopia. Similarly, the current study found that the majority of small holder dairy producers used human labor for raw milk transportation. The use of milk transportation in this study was consistent with Wayua *et al.* (2012), who stated that human labor, car and cart horse transportation systems of raw milk are not suitable, especially when important hygiene and food safety considerations were taken into account because they do not provide facilities for refrigeration at Isiolo district, Kenya. This might be due to lack of mitigation strategies and regulation policy implementation, which is crucial to mitigating postharvest losses of milk in the study milk sheds. The current findings were in agreement with those of the sub-Saharan African countries, which face documented challenges with food insecurity and nutrition. Food availability could be increased by reducing postharvest losses without further exploitation of resources (Brian *et al*., 2020).

Generaliy, to ensure the quality and safety of milk produced and marketed in the study milk sheds, it is crucial to identify the root cause of milk postharvest losses and implement the measures required to improve hygienic milk handling, milking storage, milking equipment, the provision of solar based refrigerators or regular electricity power supplies and the use of clean containers to extend the shelf life of the milk and help farmers in the study milk sheds combat spoilage and milk postharvest losses.

CONCLUSION

The results of the current findings indicated that poor milk handling, spoilage, lack of access to milk marketing, lack of cooling facilities, lack of transportation and lack of infrastructure were the major causes of milk postharvest losses and spoilage. The majority of the respondents (92.9%) reported that the common milking equipment used for milking was plastic buckets. Only (4.7%) and (2.4%) of the respondents reported stainless steel and iron buckets, respectively. The total milk postharvest losses in the study milk sheds were milk forced to be consumed, milk rejected from producers to collectors and milk rejected at collectors. In conclusions, milk postharvest losses were highest in the Addis Ababa-Selale and Ambo-Waliso milk sheds. Milk forced to be consumed; milk rejected from producers to collectors and losses at the collector's point were predicted to be the highest losses along the study of milk sheds. Finally, it is recommended that mitigation strategies should be implemented on hygienic milk handling, the provision of solar based refrigerators, an uninterrupted electric power supply, keeping milk in cold water and clean milk storage in the study milk sheds.

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Conflict of interest

The authors declared that there are no conflict of interest between authors and organization regarding this research paper.

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