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Milk Quality and its Improvement Options in Selected Milk Sheds of Ethiopia

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Abstract

The study was conducted in Selale- Addis, Adama-Asella, and Ambo-Woliso milk sheds with the objectives to evaluate the quality of raw milk, identify factors affecting milk quality and suggest quality improvement options. A value chain approach was employed where milk samples were collected from 54 smallholder dairy producers, 9 milk collectors, 27 milk retailers and 27 milk consumers from the selected milk sheds. Focus group discussions and key informant interviews were held with farmers and experts of the respective zones and woredas of the study areas. Milk collectors, processors and consumers were interviewed using semi-structured questionnaires separately prepared for each actor. The collected quantitative data were analyzed using SAS software, version 9.4. The results revealed that, the physical qualities (specific gravity, moisture content and freezing point) and chemical qualities (total solid, protein, fat, lactose and solid non-fat contents) of raw cow milk were within the normal range of raw milk set by the Ethiopian Standard Institute. The overall mean pH value of raw milk in the milk sheds was lower than the pH value set by the Ethiopian Standard Institute for raw cow milk which is also confirmed by higher titratable acidity of milk obtained in the present study. The lower pH and higher titratable acidity values may reveal that the milk might have stayed on farm for longer time before it came to collection site where the milk samples were taken. Significantly higher total bacterial count (7.23log10cfu/ml) was recorded for milk samples collected from retailers while the lowest TBC (6.46^b±0.14) was for milk samples collected from producers. The higher TBC could be related to environmental contaminants and unsanitary milk storage and transportation equipment along the milk value chain. Significantly higher CC were observed in milk samples collected from retailers (5.43±0.10 log10 cfu/ml) and consumers (5.47±0.10 log10 cfu/ml) indicating that CC increases along the value chains which could be related to poor environmental hygiene, poor hygienic milking practices and handling. In general the microbial quality of milk in the study milk sheds was found to be substandard. Unhygienic milking practices used by the farmers, shortage of clean water, lack of quality feed and feeding practices, health of animal, adulteration of milk, inappropriate milk storage and transportation systems, absence of standard milk equipment and basic requirements for milk collection, market problems, unhealthy competition among legal milk collectors/traders and illegal traders, and lack of milk regulatory system were the major factors affecting the quality of milk in the study milk sheds. Capacitating stakeholders involving in milk production, collection and marketing through skill training, improving the supply of clean water, controlling feed quality and feeding practices, improving animal health services, creating market linkages and enforcing milk regulatory systems are suggested to improve the quality of milk in the study milk sheds.

Keywords: Milk quality; hygienic practices; milk adulteration; regulatory system; milk shed

Introduction

Milk plays a vital role in human nutrition when it is of high quality and safe for consumption. The dairy industry in Ethiopia has largely neglected the implementation of quality assurance systems though the Ethiopian Standards Authority has established guidelines for both domestic and imported dairy products. As a result, the Ethiopian milk production chain faces significant challenges in meeting milk quality standards and consumers demands. Consumers need consistent high-quality dairy products, which are important for producing milk with a longer shelf life that ensures safe and nutritious food (Jessica et al. 2014).

In the absence of milk regulatory system, it is difficult to maintain a consistent supply of quality milk. Insufficient post-handling practices including poor hygiene of milk equipment, storage containers, transportation, and retail practices predispose the milk to microbial contamination (Azeze and Bereket, 2016). In Ethiopia the price of milk is usually determined by volume rather than quality. Milk rejected by one collector is purchased by another leading to unhealthy competition among the collectors. This competition has forced processors to pay higher prices for inferior quality milk, consequently leading to higher prices for dairy products (Abunna et al. 2019; Keba et al. 2020).

Milk quality and safety in Ethiopia are reported to be below standard due to insufficient pre-milking and post-harvest handling practices and the absence of effective milk quality regulatory systems. The physco-chemical properties and microbial content of milk and milk products serve as indicators of milk quality and also reflect the hygienic levels during milking, storage, transportation and marketing of milk (Getabalew et al. 2020). Furthermore, researches in the past have concentrated much on increasing milk production without giving much emphasis on milk quality (Gemechu, 2017). Thus, understanding the current status of milk quality, the factors affecting milk quality and suggesting quality improvement strategies are very important to strengthening the production and supply of quality milk across the country. Moreover, identifying the institutions responsible for milk and milk products quality control in the country is crucial to foster collaboration, clearly defining roles and leveraging the synergies of the institutions to improve milk quality in the future.

Methodology

Description of the study areas

The study was conducted in Selale-Addis, Ambo-Woliso, and Adama-Asella milk sheds. The South West Shoa Zone/Woliso 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. West Shoa zone/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 East Shoa and Arsi Zones/Adama-Asela are situated between 38°41' and 40°44' E longitude and 6°79' and 8°49' N latitude. The areas range from 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 annual average rainfall of the areas ranges between 901mm and 1200mm. The North Shoa Zone/Selale is located 114 kilometers north of Addis Ababa, in the Oromia Regional State. It receives 1200 mm of rain annually and is situated at 9° 48′ N latitude, 38° 44′ E longitude, and has an elevation of 2,738 to 2,782 meters above sea level. The annual temperature varies between 6°C and 21°C (NSZLFO, 2017).

Data collection methods

Focus group discussion and key informant interview were employed to assess hygienic milk handling practices and factors affecting milk quality in the study areas. Two focus group discussions per district were held with farmers/producers having 8 to 10 members per group using a checklist to guide the discussion. The key informants/experts interview was held with agriculture head and experts working with dairy cattle, animal health, cooperatives and trade office at different administration levels. Milk collectors (cooperatives, unions, traders) and processors were interviewed using semi-structured questionnaires separately prepared for each actor.

Milk Sampling Techniques

Milk samples were collected from Wolmera, Ejere, Sebeta, and Woliso districts of Ambo-Woliso milk shed; Girar Jarso, Sululta, and Wachale districts of Selale-Addis milk shed and Adama, Lume, and Digalu Tijo districts of Adama-Asella milk shed. A value chain approach was employed where milk samples were randomly collected from smallholder farmers, milk collectors, retailers and consumers. A total of 117 milk samples (54 milk samples from smallholder dairy producers, 9 samples from milk collectors, 27 samples from milk retailers and 27 milk samples from consumers) were collected from the three milk sheds and analyzed for physicochemical and microbial qualities. About 250 ml of milk sample was collected from each producer, collector, retailer, and consumer in the morning. Milk samples were collected aseptically in sterile bottles kept in an ice box and transported to Holeta Dairy Technology Laboratory for analysis. The milk samples were kept in the refrigerator at 4°C until laboratory analysis.

Physicochemical quality analysis of raw milk

The collected milk samples were analyzed using the lacto-scan LAC-SPA manufacturer company to evaluate the physicochemical properties (specific gravity, freezing points, pH) and composition (moisture content, lactose, protein, fat, SNF, and ash) and the analysis was done in triplicate as per the protocol of the manufacturer company.

Titratable acidity test of raw milk

Ten ml of milk sample was pipetted into a beaker and then 3-5 drops of 0.5% phenolphthalein indicator was added. Then the milk sample was titrated with 0.1N NaOH until the pink color persisted. Lactic acid percentage was used to express the milk's titratable acidity (O'Connor, 1995).

Microbial quality analysis of raw milk

The total bacterial count (TBC), total coliform count (TCC) and yeast and mold count (YMC) of raw milk were undertaken for milk samples collected from different stages of the dairy value chain of the milk sheds.

Total bacterial count (TBC)

To determine the total bacterial count, 1ml of milk was added to a sterile test tube containing 9 ml of peptone water. After thoroughly mixing, the sample was serially diluted up to $1:10^{-5}$ and $1:10^{-6}$, and duplicate samples (0.1 ml) were poured onto a plate using 15-20 ml of standard plate count agar solution and mixed thoroughly. The culture was incubated at 25^0C for 24 hours, and plates with an acceptable number of colonies (30-300) were considered for enumeration using a colony counter (Richardson, 1985).

Total coliform count (TCC)

In a sterile stomacher tube, 10mL of milk sample was mixed with 250 mL of peptone water (1%). After mixing, the sample was serially diluted up to $1:10^{-2}$ and $1:10^{-3}$ in sterile test tubes containing 9ml of peptone water, and duplicate milk samples (1ml) were plated using 15-20 ml of Violet Red Bile Agar (VRBA) in a sterile petri dish. After thoroughly mixing, the plated sample was allowed to solidify and then incubated at 35^0C for 24 hours. Following incubation, all colonies were counted under the colony counter, and results from each plate, which contained 25 to 250 colonies per plate were recorded (Richardson, 1985).

Yeast and mold count (YMC)

The milk samples were analyzed for the presence and concentration of yeasts and molds. One ml of milk sample serially diluted in $1:10^{-4}$ and $1:10^{-5}$ using peptone water and duplicate samples were plated using 15-20 ml of Potato Dextrose Agar

(PDA). The plates were incubated at 25^0C for 48 hours (FAO, 1997). Following incubation, all colonies were counted under the colony counter.

Methods of data analysis

The analysis of variance (ANOVA) in SAS software, version 9.4 (2016) was used to analyze the physico-chemical and microbiological loads of raw milk data. Means were separated using the least significant difference (LSD) test when ANOVA declares significant difference among means. The significance difference was reported as a p-value ($p \leq 0.05$). The following mathematical formula was used to express the number of microorganisms (colony-forming units) present in each milliliter of milk samples (FDA, 2003).

$$N = \frac{\sum C}{(N1 * 2) + (0.1 * n2)} * d$$

Where,
N = Number of colony-forming units per ml of milk
∑C = Sum of all colonies counted on plates
n1 =Number of plates in the first dilution counted
n2 =Number of plates in the second dilution counted
d =Dilution factor of lowest dilution used.

Microbial count data was first transformed into logarithmic values (log10) before statistical analysis. The log10 transformed values were analyzed using the General Linear Model (GLM) of SAS (2016) software.

Yij= µ + Li+ Cj + eij
Where
Yij=Dependent or response variables (Physicochemical, compositional and microbial load)
µ = Overall mean of respective variable (milk sheds and market chain)
Li= Site effect to the i^{th} milk shed (i=3, Selale-Addis, Ambo-Woliso and Adama-Asella), Cj=Collection effect with j^{th} market chain (j=4, producers, milk collectors, retailers, and consumers) and eij = Random error

Results and Discussion

Physical quality of raw milk Specific gravity

The overall mean specific gravity of the raw milk in the study milk sheds are indicated in (Table 1). The current study revealed that the specific gravity of raw milk was significantly ($p<0.05$) different across the milk sheds and the market chain. The highest specific gravity of milk was observed for Selale-Addis milk shed, while the lowest was for Ambo-Woliso milk shed. Within the milk sheds, the highest specific gravity (1.036 g/cm^3) was observed for milk sampled from collectors, whereas the lowest (1.032g/cm^3) was for milk from producers. The highest specific gravity of milk from collectors could be due to the removal of cream or fat that leads to increase the specific gravity of raw milk. No significant differences in specific gravity of milk were observed for milk sampled from collectors, retailers and consumers (Table 1). The specific gravity of normal milk ranges from1.026-1.032 (IES, 2021). Thus, the specific gravities of raw milk from Adama-Asella (1.035g/cm3) and Ambo-Woliso (1.033g/cm3) milk sheds were found to be higher than the normal specific gravity ranges set for raw milk. The specific gravity of milk, among others, is commonly used for quality tests, mainly to check for the addition of water to milk or the removal of cream (O'Connor, 1994).

Water content

The overall mean water content of milk collected from the three milk sheds was 86.37±0.21% (Table 1). There were no significant difference ($p>0.05$) among the moisture contents of raw milk collected from study milk sheds. The current results revealed that the moisture contents of raw milk were significantly ($p<0.05$) different across the market chain in the study milk sheds. The lowest milk moisture content (86.40±0.15%) was observed for raw milk sampled from producers. The overall mean moisture content of raw milk (86.37±0.21%) observed in the study milk sheds is comparable with the results of Abdissa et al. (2020) who reported the overall mean moisture contents of 86.04±1.10% in Abuna Gindeberet district. The overall mean moisture content of raw milk observed in the present study is within the normal ranges of raw milk moisture content (85.5 to 89.5%) reported by FAO (2009).

Freezing point

The overall mean freezing point of raw milk in the study milk sheds was -0.54±0.01^{0}C (Table 1). There were no significant differences in freezing points of raw milk collected from the three milk sheds (Table 1). The freezing point of raw milk was significantly ($p<0.05$) differed along the milk market chain within the milk sheds. The overall mean freezing point (-0.54±0.01^{0}C) of raw milk obtained in the study milk sheds was in agreement with the finding of Desalegn (2017) who reported a mean freezing point of -0.55±0.03^{0}C for raw milk. In contrast to the current finding, Shimelis (2016) reported a mean freezing point of -0.941±1.40^{0}C for milk collected from Addis Ababa. According to the Ethiopian Standards Agency, the normal freezing point of raw milk ranges between -0.55^{0}C and-0.525^{0}C (ESA, 2009). Thus, the mean freezing point obtained in the current milk sheds was almost within the normal ranges of raw milk freezing point set by the Ethiopian standard agency.

pH-Value

The overall mean pH of raw milk across the three milk sheds was 6.51±0.05 (Table 1). There was a significant difference in pH-values ($p<0.05$) of the raw milk across the study milk sheds and market chain. Ambo-Woliso milk shed had significantly lower pH of raw milk (6.37). At producer level, the pH of raw milk (6.68) was within the normal range; however it is slightly decreased in the subsequent stages of the milk value chains (from collectors to consumers). This indicates that milk could develop acidity during transportation if it doesn't reach to the processing plants or the consumers quickly or if it is not transported in refrigerated trucks.

Table 1: Physico-chemical quality of milk in the study milk sheds (Mean ± SE)

Parameters	Sample size (N)	Specific gravity (g/cm3)	Moister Content (%)	Freezing Point (^{0}C)	pH (M scale)	Titratable acidity (%)
Milk sheds						
Adama-Asella	39	1.035^a±0.01	86.74±0.24	-0.55±0.01	6.63^a±0.03	0.34^{ab}±0.03
Selale- Addis	39	1.036^a±0.02	86.16±0.21	-0.55±0.01	6.53^{ab}±0.05	0.25^b±0.04
Ambo-Woliso	39	1.033^b±0.02	86.20±0.23	-0.53±0.02	6.37^b±0.02	0.40^a±0.02
Overall mean	117	1.035±0.01	86.37±0.21	-0.54±0.01	6.51±0.04	0.33±0.03
P-value		0.0047**	0.2519	0.7455	0.0017**	0.0079**
Market chain						
Producers	54	1.032^b±0.00	86.40^b±0.15	-0.57^a±0.01	6.68^a±0.08	0.22^b±0.02
Collectors	9	1.036^a±0.00	87.18^{ab}±0.37	-0.54^{ab}±0.02	6.53^b±0.03	0.31^{ab}±0.05
Retailers	27	1.034^a±0.00	87.38^a±0.22	-0.53^b±0.01	6.47^b±0.05	0.46^a±0.03
Consumers	27	1.035^a±0.00	87.16a±0.22	-0.54^b±0.01	6.47^b±0.05	0.44^a±0.03
Overall mean	117	1.034±0.00	87.03±0.24	-0.55±0.01	6.54±0.05	0.36±0.03
P-value		0.0002***	0.0008***	0.0388*	0.0004***	0.0001***

^{a,b,} superscripts in column with different letters for a given physicochemical properties of milk are significantly different, *, **, *** significant at $p<0.05$, $p<0.01$ and $p<0.001$, respectively.

The overall mean pH-value obtained in the present study is comparable with the result of Jalel et al. (2021) who reported pH-values of 6.41±0.05, 6.28±0.04 and 6.24±0.03 along the milk value chains of Burayu, Sebeta, and Sululta of Oromia special zones, respectively. According to O'Connor (1995) and FAO (2009), fresh cow's milk at 20^{o}C typically has a pH value that ranges between 6.6 to 6.8. The mean pH value of raw milk observed in the current study milk sheds is lower than the normal pH range of fresh milk set by the Institute of Ethiopian Standard (IES, 2021).

Titratable acidity

The average titratable acidity of raw milk in the study milk sheds was 0.33±0.03% (Table 1). Significant differences in titratable acidity ($p<0.05$) were found across the study milk sheds and market chains. The highest titratable acidity was observed in the Ambo-Woliso milk shed (0.40%), while Selale-Addis milk shed reported the lowest (0.25%). Within the milk sheds, milk collected from retailers had the highest titratable acidity (0.46%), while milk from producers had the lowest (0.22%). According to the Ethiopian Standards Agency (ESA, 2009), the normal range for titratable acidity in fresh milk is between 0.14 and 0.17%. The higher acidity levels observed in this study is likely resulted from poor milk handling, inadequate cooling facilities and prolonged storage by collectors, retailers, and consumers, which may have promoted bacterial growth.

Chemical quality of raw milk

Total solids (TS)

The overall mean total solid (TS) content of raw milk in the study milk sheds was 12.97±0.20% (Table 2), with no significant effect of milk sheds ($p>0.05$) on TS levels. However, raw milk samples from producers had significantly higher TS content (13.59±0.15%) compared to the subsequent stages of the milk value chain (Table 2). The reduction in TS content along the milk market chain might be due to the removal of cream and reduction of fat along the chain as revealed in Table 2. In contrast to the present result, the mean total solid (12.18± 0.55) of raw milk was not significantly varied ($p>0.05$) among the milk value chains of Wolmera and Ejere districts of West Shewa Zone (Hirpasa, 2014). However, it is lower than the report of Rahel (2008) and Alganesh (2002) who reported 13.8 and 14.3% total solids for milk samples collected from Wolayta and East Wollega Zones, respectively. Significantly lower total solids (11.30 and 11.38%) were reported by Nigusse (2006) and Desalegn (2017) in market chains of Mekele, Bishoftu and Akaki towns, respectively. These variations might be due to differences in breed, feed types and feeding system. The overall average TS content of (12.97±0.20%) obtained in the current study is comparable with the results of Gemechu (2017), who reported an average TS content of 12.24% in peri-urban areas of Ejere, Wolmera, Selale, and Debre Birhan districts of the central highlands of Ethiopia. The TS content of raw milk in the study milk sheds is within the minimum average TS content for unprocessed whole cow milk (12.8%) set by the Ethiopian Standards Agency (IESA, 2021).

Fat content

The overall mean fat content of raw milk in the study milk sheds was 3.43±0.05% (Table 2). Fat contents varied significantly ($p<0.05$) across the study milk sheds and market chain. Significantly higher fat content was observed in Adama-Asella (3.54±0.05%) milk shed compared to the other milk sheds. Fat content significantly reduced along the milk market chain likely due to the removal of cream along the chain. The higher fat content was recorded at milk producers' level. The mean fat content obtained in the present study areas is lower than the findings of Abdissa et al. (2020), Dessalegn (2017) and Teshome et al. (2015) who reported fat contents of 4.19±0.70 % in Abuna Gindeberet, 3.60±0.53% in Bishoftu-Akaki and 4.28±0.05% in Shashamane, respectively while it is comparable to the minimum standard set for raw milk (3.5%) by the Ethiopian standard authority (ESA, 2009). The present result is also lower than the value (6.10%) reported for Horro breed in the eastern Wollega (Alganesh, 2002). Similarly, Lemma (2004); Asaminew (2007) and Rahel (2008) reported higher fat content value (6.3%, 4.71%, and 5.35%) for local breed in east Shoa, Mecha and Bahir Dar Zuria and Wolayta Zone, respectively. These variations could be attributed to the difference in the cow breeds, type of feed, age and stage of lactation.

Protein content

No significant difference (p>0.05) in protein contents of raw milk was observed across the milk sheds (Table 2).

Table 2: Chemical composition of milk along the market chain and milk sheds (Mean ± SE)

Parameters	Sample size	Total Solid (%)	Fat (%)	Protein (%)	Lactose (%)	SNF (%)	Ash (%)
Milk shed							
Adama-Asella	39	13.26±0.21	3.54^{a}±0.04	3.23±0.04	4.86^{a}±0.24	9.52±0.20	0.68±0.02
Selale-Addis	39	12.84±0.21	3.37^{b}±0.03	3.25±0.04	4.73^{a}±0.23	9.46±0.22	0.65±0.01
Ambo-Woliso	39	12.80±0.19	3.38^{ab}±0.05	3.24±0.04	4.07^{b}±0.25	9.41±0.21	0.66±0.01
Overall mean	117	12.97±0.20	3.43±0.04	3.24±0.04	4.55±0.23	9.46±0.21	0.66±0.01
P-value		0.2519	0.0424*	0.9745	0.0176*	0.5585	0.2434
Market chain							
Producers	54	13.59^{a}±0.15	3.87^{a}±0.03	3.40^{a}±0.03	4.77±0.16	9.72±0.14	0.72^{a}±0.00
Collectors	9	12.81^{ab}±0.37	3.30^{b}±0.08	3.20^{ab}±0.07	4.59±0.41	9.50±0.36	0.68^{ab}±0.02
Retailers	27	12.61^{b}±0.21	3.23^{b}±0.05	3.18^{b}±0.04	4.51±0.23	9.38±0.21	0.65^{b}±0.01
Consumers	27	12.83^{b}±0.21	3.23^{b}±0.05	3.17^{b}±0.04	4.66±0.23	9.51±0.21	0.62^{b}±0.01
Overall mean	117	12.97±0.24	3.43±0.06	3.23±0.05	4.63±0.26	9.53±0.23	0.67±0.01
P-value		0.0008***	0.0001***	0.0001***	0.8444	0.5799	0.0001***

Eth. = Ethiopia, ^{a,b}, superscripts in the same column with different letters superscripts for a given chemical composition of milk is significantly different, *, **, *** significant at p<0.05, p<0.01 and p<0.001, respectively.

The overall mean protein content (3.24±0.04%) obtained in the current study is comparable with the minimum standard of milk protein (3.2%) set by the Ethiopian Standard Authority (IES, 2021). The result is also in agreement with the result of Desalegn (2017) who reported the protein contents of (3.20±0.22%) in Bishoftu and Akaki Towns. However, milk samples collected from producers had significantly higher protein content (3.40±0.03%) compared to those from subsequent stages in the milk market chain. Abdissa et al. (2020) reported the overall mean protein content of 3.53±0.26 in Abuna Gindeberet district which is higher than the present result (3.24±0.04%) whereas Dehinnent et al. (2013) reported 3.12±0.32% protein content in selected areas of Amhara and Oromia National Regional States, Ethiopia which is lower than the present result.

Lactose content

Significantly higher lactose content (p<0.05) was observed in Adama-Asella (4.86±0.24) milk shed. No significant differences (p>0.05) in the lactose content of milk were observed across the milk market chains (Table 2). The overall mean lactose content in the present study milk shed (4.55±0.23) is lower than the finding of Abdissa et al. (2020) who reported the overall mean lactose content of 5.39±0.31% in Abuna Gindeberet district. However, higher average lactose content was (4.34±0.13%) reported by Belay and Janssens (2014) in the dairy value chain of Jimma town. The lactose content of milk in the current study milk sheds exceeds the minimum lactose content (4.20%) set by the European Union (Tamime, 2009) and almost comparable with the standard milk lactose (4.60%) set by the Institute of Ethiopian Standard (IES, 2021).

Solid not fat (SNF)

No significant difference ($p>0.05$) in SNF content of milk were found among the milk sheds and market chains. The overall mean SNF observed in the current study (9.46±0.21%) is lower than the finding of Abdissa et al. (2020) who reported the overall mean SNF of 9.77±0.58 in Abuna Gindeberet district. However, Dessalegn (2017) and Jalel et al. (2021) reported higher average SNF content of 7.78±0.41% and 7.59±0.17% in the dairy value chain of Bishoftu and Akaki towns and Oromia special zone, respectively. These variations could be related to variations in interval between milking, stage of lactation, age, and feeding as solids-not-fat content is more sensitive to feeding level. The overall mean SNF content of milk obtained in the current study is higher than the minimum SNF percent standard (8.5%) set by European Quality Standards for unprocessed whole milk (Tamime, 2009).

Ash content

Ash content of milk did not vary among the milk sheds. However, significantly higher (0.72±0.00%) ash content was observed for the milk sampled from producers. The overall mean ash content obtained in the current study (0.66±0.01) is lower than the finding of Jalel et al. (2021) who reported the overall mean ash content of 0.73±0.01, 0.74±0.02, and 0.69±0.02% in the dairy value chains of Burayu, Sebeta, and Sululta of Oromia special zone, respectively. This value is also below the normal standard (0.70%) set by the Institute of Ethiopian Standard (IES, 2021) and 0.7 to 0.8% reported by O’Connor (1994).

Microbial quality of raw milk

Total Bacterial Count

The total bacterial count (TBC) per ml of raw milk in the study area was 6.91±0.20 log10cfu/ml (Table 3). TBC did not vary among the different study milk sheds. However, significantly highest TBC (7.23log10cfu/ml) was recorded in milk samples collected from retailers, while the lowest TBC (6.46^{b}±0.14) was found from milk samples collected from producers. The current TBC of raw milk is higher than the results of Estifanos et al. (2015) and Abdissa et al. (2020) who reported the total bacterial count of 6.24±0.87 log10 CFU/ml in the dairy value chains of Harar and 5.99±0.35 log10 CFU/ml in Abuna Gindeberet district, respectively. The higher TBC in this study may be attributed to environmental contaminants, unsanitary milk equipment, dirty udders and teats, and mastitis causing organisms. TBC estimates the total number of aerobic bacteria in raw milk and is a common method to measure the hygienic quality of milk at the farm level. Factors such as storage temperature and time since milking also affect milk quality by influencing bacterial growth. A high level of TBC ($> 10^6$ cfu/ml) is associated with increased enzymatic activity that can result in textural and flavour defects in raw milk and processed dairy products (Murphy et al. 2016).

Coliform Count

Significantly higher coliform counts (CC) were observed in milk samples collected from retailers (5.43±0.10 log10 cfu/ml) and consumers (5.47±0.10 log10 cfu/ml) indicating an increase in CC along the value chains. This increase could be related to poor environmental hygiene, poor hygienic milking practices and further handling. Coliforms in milk primarily come from the cow's environment and their presence in milk is an indicator of faecal contamination, often from soiled udders and teats. High CC ($> 10^3$ cfu/ml) in raw milk may reflect poor environmental hygiene, poor hygienic milking practices and further handling, improperly cleaned milk equipment, contaminated water, inadequate refrigeration, or the presence of coliform mastitis (Martin et al. 2016). The overall mean coliform count of raw milk sampled from the three milk sheds was 5.31±0.10 log10 cfu/ml (Table 3) which is almost close to the minimum Ethiopian standard value ($5x10^5$) set by the Ethiopian Standard Agency (ESA,2009). The present result is also comparable to the findings of Hirpasa (2014) and Estifanos (2015) who reported mean coliform counts of 5.41±0.11 log_{10} cfu/ml and 5.44±0.81 log10 cfu/ml for raw cow milk in the milk value chain of Holeta-Ejere and Harar town, respectively. Godefaye and Molla (2000); Alganesh (2002); Rahel (2008); Zelalem (2012); Solomon et al.(2013) and Dehinenet et al. (2013) reported values lower than the present result whereas Abdissa et al. (2020) reported a much higher coliform count of 8.13±0.31 log10 cfu/mL in Abuna Gindeberet district. These variations could be attributed to insufficient pre-milking and udder preparation, poor hand washing practices by milkers', the use of poor quality equipment, and non-boiled water for cleaning milking utensils that introduce the pathogen to milk.

Table 3: Microbial load of raw milk in the study milk shed and market chain (Mean ±SE)

	Microbial load of raw milk			
Parameters	**Sample Size (N)**	**TBC (log10cfu/lm)**	**CC (log10cfu/lm)**	**YMC (log10cfu/lm)**
Milk shed				
Adama-Asella	39	6.80±019	5.27±0.11	7.04±0.31
Selale-Addis	39	6.87±0.20	5.29±0.13	6.79±0.31
Ambo-Woliso	39	7.08±0.21	5.36±0.15	6. 67±0.31
Overall mean	117	6.91±0.18	5.31±0.10	6.83±0.31
P-value		0.5941	0.1430	0.7101
Market chain				
Producers	54	6.46^{b}±0.14	4.64^{b}±0.07	6.21^{b}±0.22
Collectors	9	6.93^{ab}±0.34	5.27^{a}±0.17	6.57^{ab}±0.54
Retailers	27	7.23^{a}±0.20	5.43^{a}±0.10	7.43^{a}±0.31
Consumers	27	7.06^{ab}±0.20	5.47^{a}±0.10	7.28^{a}±0.31
Overall mean	117	6.92±0.22	5.20±0.11	6.87±0.35
P-value		0.0082**	0.0001***	0.0044**

^{a,b}, superscript in the same column with different letters for a given microbial load of milk are significantly different, TBC=Total bacteria count, CC=coliform count, YMC=Yeast and mold count, cfu/ml=colony forming unit/milliliter, log10-Logarithms of 10 , **, *** significant at p<0.01 and p<0.001, respectively.

Yeast and Mold Count

Significant difference (p<0.05) were observed in yeast and mold counts (YMC) across different stages of the dairy value chain in the study milk sheds (Table 3). Milk collected from retailers had a significantly higher YMC (7.43a±0.31 log10 cfu/ml) compared to milk from producers, which had a lower (6.21b±0.22 log10cfu/ml). However, there were no significance differences (p>0.05) in YMC of milk samples among the study milk sheds. The overall mean yeast and mold count (6.83±0.31log10cfu/ml) in the present milk sheds is lower than the 7.24±0.21 log10 cfu/ml reported by Abdissa et al. (2020) in Abuna Gindeberet district. The high YMC obtained in the present study might be due to contamination of milk during milking, poor milkers' hygiene, extended storage and inadequate milk handling and lack of cooling facilities during transportation along the dairy value chain.

Factors affecting milk quality in the study areas

Unhygienic milking practices used by the farmers

According to the focus group discussion held with milk producers, barn cleaning, keeping personal hygiene, cleaning milk utensils and keeping the health of milking cows were the major hygienic milking practices used by the milk producers in order to produce quality milk in the study milk sheds (Table 4). It was also observed that milk producers in the study milk shed have better awareness on the hygienic milking procedures to be followed in order to produce quality milk. The majority (67.7%) of farmers in the study areas use traditional non- food grade utensils for milk storage and transportation that could be, among others, one source of contaminations affecting milk quality in the study milk sheds. However, additional awareness creation should be arranged to milk producers on the importance of hand washing, udder washing and use of food-grade utensils in the study milk-sheds to better improve/ensure quality milk production.

Table 1: Hygienic practices followed by the milk producers in producing quality milk in study areas

Hygienic procedures followed by producers		Milk sheds			Overall mean (%)
		Wolmera-Addis	Salale-Addis	Adama- Asella	
Barn cleaning	Yes	100	100	100	100
	No	0	0	0	0
Udder washing	Yes	100	100	0	66.7
	No	0	0	100	33.3
Personal hygiene	Yes	100	100	100	100
	No	0	0	0	0
Utensil cleaning	Yes	100	100	100	100
	No	0	0	0	0
Using food grade utensils	Yes	0	100	0	33.3
	No	100	0	100	66.7
Keeping the health of cows	Yes	100	100	100	100
	No	0	0	0	0

Shortage of clean water

Availability and use of clean water is also one of the important factors affecting quality milk production. According to the focus group discussion, almost all the milk producers in the study milk-sheds were well aware of the importance of using clean water to ensure quality milk production though they are constrained by the availability of clean water in their areas.

Lack of quality feeds and feeding practices

Availability of quality feed is another important factor affecting quality milk production. According to the current study farmers were constrained by shortage, high price and poor quality of concentrate feed. In order to minimize the effect of feed quality on milk quality, farmers in the study area usually try to buy animal feed from known sources like cooperatives and feed processing factories. Unless forced to do so, they don’t buy animal feed from individual feed traders as they mostly adulterate the feed with non-feed materials like saw dust. To avoid contaminations of the purchased feed from fungus, farmers use racks and dry clean storages. These could minimize contamination of feed with fungus that results in aflatoxin. Milk producers in the study area identify the contaminated feed using visual observation. During the focus group discussion, farmers complained that there is no organization or regulatory body that controls the quality of feed. Thus, deployment of animal feeds standards and labeling systems and enforcing feed quality control system should be in place in order to improve feed quality and thereby improve the quality of milk in the study milk-sheds.

Health of animal

The first step in ensuring farm to fork milk quality and safety is producing quality milk under hygienic conditions from healthy animals. Thus, ensuring the health of dairy animals is critical for maintaining milk quality. If the milking cows get sick and under treatment, farmers in the study areas normally milk the cows and supply this milk to market, few milk collectors (Holland dairy) usually receive the milk from cows under treatment and dump it if the producers genuinely inform that it is from cows under treatment. Regular veterinary care, vaccination programs, and disease prevention measures help prevent the spread of disease and ensure the quality of milk in the study area.

Adulteration of milk

In previous reports there were some common adulterants such as water, starch, and even harmful substances like formalin that affect the quality of milk. More distressingly, formalin, a toxic substance used in industries as preservative, has been detected as an adulterant in some cases. This can have severe health consequences when consumed. Adulteration can occur at various stages of the milk supply chain, from farm to market. According to the key informant interview, milk in the study area is adulterated by addition of water; to increase the volume of milk, salt and powder to adjust the milk quality parameters such as specific gravity and fat readings. Water is commonly added to milk as a means to increase the volume to get un-necessary benefit. These adulterations not only lower the nutritional value of milk but also increase the risk of bacterial contamination in milk if proper hygienic practices are not followed. To address these issues, it's crucial to have strong quality control measures in place, including regular inspections and testing of milk samples. Additionally, raising awareness among consumers about the potential risks of milk adulteration and providing them with information on how to identify reputable sources can contribute to combating this problem. It's important for all stakeholders, including regulatory bodies, farmers, processors and consumers, to work together to ensure the safety and integrity of milk in the study milk sheds.

Inappropriate milk storage and transportation systems

According to the information obtained from key informant interview (KII) and researchers’ observation, there were absence of food grade milk utensils under farmers’ condition; farmers use Jerry cans and paint cans for milk transportation using carts, donkey and horseback as means of transportation that can affect the quality of milk. Cooperatives and processors have no standard collection center and cold chain transportation system; they use Bajaj, open pickups, automobile and ISUZU which could affect the quality of milk. The majority of milk processors use standard milk cans.

Absence of standard milk equipment and basic requirements for milk collection

In issuing the license to milk traders/collectors, the concerned body should look into the capacity of milk traders and very requirements needed for milk collection like the presence of standard milk equipment (stainless steel), cold storages and appropriate vehicles. According to the information obtained from key informants and researchers' observations, the reality on the ground is quite different. Milk is collected using sub-standard milk utensils, majority of the individual traders and cooperatives have no cold chain transportation facilities and the vehicles used for milk collection are not meant for milk collection and these can expose milk for contaminations. Moreover, the majority of the collectors involve in milk collection without having certificate of competence as there is no strong regulatory system in the study areas. According to our live observations in Wolmera district, there were individual people who collect milk illegally using their own Automobile car.

Market Problem

Several marketing constraints have been reported during the group discussion and key informant interviews in the study areas. Among the marketing constraints, low and seasonal fluctuation of milk price is the most critical issues stressed by the group members. The price paid by different collectors also varies. According to them, price paid to milk is not proportional to the cost of milk production because the input costs are increasing every time. Producers cannot determine/set the price of their milk as price is normally set by milk collectors/processors.

Table 2: Milk price across milk value chain in the study milk sheds (2024)

Market chain	Milk price (ETB)		
	Wolmera-Addis	Salale-Addis	Adama- Asella
Producers- cooperative	40.00	45.00	40.00
Producers- traders	40.00-45.00	46.00	45.00- 50.00
Cooperatives- processors	45.00	50.00	50.00

According to the milk producers, there is no institution that determines the minimum selling price of milk considering its cost of production. This report is in line with the report of ATA (2017) which stated that dairy producers and downstream actors in the value chains face many challenges in getting milk to market, for the most part, milk collection, chilling and transport are not well organized and market fails to pay fair prices for milk producers which in turn failed to ensure the supply of quality milk to the consumers.

Absence of strong regulatory system, presence of illegal milk collectors, dishonesty of milk collectors in checking the quality of milk to use as mechanism to set down or reduce the price of milk, absence of contract agreement between milk suppliers/producers and milk collectors, deliberate rejection of quality milk by the agents to bribe with the producers were also reported as major constraints of milk marketing in the areas. Absence of Legal binding agreements and lack of clear laws and policies enforcement mechanisms affect the income of the producers. The informality of the selling-purchasing agreements also implies unguaranteed end market opportunities for producers. According to the key informants at North Shewa zone of Oromia regional state, ‘’North Shewa is a tower of milk and dairy is life for the community but these days producers are not much motivated”. According to them, poor linkage and weak market coordination among actors which results in weak bargaining power of producers with buyers and decreases in their income, the quota system set by milk collectors especially during fasting periods, absence of quality based payment system, unfair competition among milk collectors i.e. milk rejected by one collector is accepted by another collectors, fraudulent behavior of collectors in measuring milk, poor awareness of the milk collectors/agents on milk quality testing and licensing issue were strongly emphasized as the major constraints of milk marketing in the area.

The key informants also suggested the establishment of milk check points at strategic locations where there should be strict control of milk at each check points *“Keellaa Aannanii*” like that of coffee so that only certified milk and licensed collectors/traders should pass the check points.

Milk should be certified at collection site to control the illegal middle men. Youth, women and producers have to be organized and directly provide the milk to processing plants. In nutshell, traders have the greatest power over the other value chain actors since they play a bigger role in setting the price of milk.

Unhealthy competition of milk collectors

According to the information obtained from focus group discussion and key informant interviews of respective districts, unhealthy competition of illegal milk collectors/traders and unhealthy competition among the formal milk collectors that is milk rejected by one collector due to poor quality is accepted by other collectors which encourage the production and entry of poor quality milk into market. Moreover, these illegal practices have made the formal cooperative out of the market in the previous time and are still weakening the formal marketing system of the same since primary cooperatives consistently refuse to accept milk of poor quality. The good practice of cooperatives should be adopted by other milk collectors and processors to improve the quality of milk produced and sold in the study milk sheds. To control these illegal practices, it is recommended that a regulatory framework should be established to enhance the production and marketing of quality milk. This will help ensure a fair and sustainable quality milk delivery system for all stakeholders involved. Thus, if improvement in quality milk is targeted in the country, there should be robust milk quality control system that discourage these illegal practices and encourage quality milk production through availing premium incentives for those producing quality milk.

Arrangement of incentives and quality based payment could be one of the strategies to improve milk quality as it enables farmers to compete for premium price through producing and supplying quality milk.

Lack of regulatory system

In Ethiopia, the responsibility for milk quality regulation is divided among multiple agencies, namely the Ethiopian Food and Drug Authority, Agricultural Inputs and Products Regulatory Authority, Ministry of Health, the Ministry of Agriculture, the Ministry of Trade and Industry, Ministry of Science and Innovation as well as Local Government Administrations and Municipalities (Ayalew, 2013; Birke and Zawide, 2019). To effectively implement the rules and regulations related to milk quality, synergy of the Federal and Regional offices is very important. This fragmentation of regulatory authority has resulted in a decentralized approach to ensuring food safety standards to be met in the country. According to the information obtained from KII, there is a mandate overlapping of agricultural office and regulatory office in controlling the quality of milk at district level. For instance the agriculture office is working on extension as well as the regulatory aspects of milk.

Based on the information of the KII, we tried to review the mandates given to different organizations by proclamation of the country. For instance, the Proclamation no. 242/2014 Article 18 (26) of Oromia give authority of livestock product control to agricultural offices which is overlapping with the mandate given to Oromia Agricultural Inputs and Products Regulatory Authority as indicated in Article 47 (1, 23 & 24) of the same Proclamation Number (Proclamation No. 242/2014). It is noted that there is overlapping of mandates among the different organizations which needs to be corrected by the responsible bodies.

In addition, there is no regulatory offices/bodies working on the livestock products at lower level administrations (zonal and district level). Due to these, the rules and regulations related to livestock products (in our case, dairy) are hardly implemented at zonal and district levels. Absence of regulatory systems at lower levels resulted in inconsistent quality standards of milk which further resulted in variations in the quality of milk produced and sold in the country. Moreover, lack of regulation can lead to inadequate monitoring and enforcement of hygiene practices, increase the risk of contamination during milk production, storage and transportation and above all greatly affects people’s trust to consume milk.

As reported by the key informants and focus group discussions, stakeholders involved in milk collection and regulation do not have enough skill on milk quality tests, milk standards and regulations. Therefore, capacitating stakeholders involving in milk collection and regulations through skill training will enhance the quality of milk in the study milk sheds. To effectively implement the rule and regulations related to milk quality, synergy of the mandated institutions and Regional and Federal and Regional Governments is very important.

Major factors affecting milk quality and suggested improvement options

Table 6. Major factors affecting milk quality and their improvement options

Factors affecting milk quality	Suggested intervention strategies	Responsible institutions
Lack of good Agricultural Practices • Poor hygienic milking practices • Poor Hygienic condition of cows and milkers • Unhygienic and substandard utensils • Lack of clean water and detergent for cleaning	• Capacity building on regular cleaning and sanitization of milking equipment, • Improve the hygienic practices in milk production • Proper hand-washing and wearing protective clothing.	• Regulatory authority • Agricultural Offices • Research Institutions • Universities • NGos
Lack of quality feed & feeding practices • Poor quality of feed and high price • No feed quality control system • Suboptimal feeding practices	• Waiving tax from animal feed • Establishing primary cooperatives on feed supply & strengthening the existing primary dairy cooperatives to supply feeds to their members • Enforce feed quality control system • Set animal feeds standards & labelling	• Regulatory Authority • Agricultural Offices • Institute of Ethiopian standard. • Cooperative Offices
Limited animal health control • No regulatory system and control on the drug withdrawal period, milk borne Disease (Mastitis, TB and others) and milk usage • Lack of veterinary drugs and animal health services	• Enforcing animal health regulations • promoting awareness • Ensuring animal health services (Vaccinations, Disease control measures) • Improve veterinary drugs & supplies in types, quality and quantity	• Agricultural Offices • Drug supply & control authority
Adulteration of milk • Dilution of milk with water at all level • Intentional addition of low-quality or harmful substances to milk • Lack of awareness and enforcement of quality regulations • Limited resources and infrastructure for testing and monitoring	• Awareness creation and promoting transparency, implementing stricter regulations, • Strengthening quality regulations and enforcement mechanisms • Initiatives have to be undertaken to improve milk testing capabilities and establish quality control laboratories	• Ministry of Trade • Trade Bureau • Inputs & products Authority • Cooperative agency • Agricultural Offices • Legal office
Low milk price (encourage water addition)	• Formulating milk pricing policy • Set price of milk based on cost of production • Implementing milk quality based payment • Set premium price for quality milk	• Ministry of Trade • Trade Bureau • Inputs & Products Authority • Cooperative agency

		• Agricultural Offices • Legal office
Market problems • Lack of standard milk collection centres • Fluctuation of market (location and time) • Presence of illegal traders • Lack of milk quality assurance and certification • Lack of licensing actors as per standard • Low price of milk • Unhealthy completion of legal & illegal traders • Lack of milk quality based payment	• Establish standard milk collection centres at strategic locations • Setting regulations on issuing the license to control illegal trade • Establishing milk quality assurance and certification systems & Certifying milk quality at collection and processing units • Strengthening the existing dairy processing cooperative unions • Improving market linkages • Promoting quality based payment/incentives for quality milk producers	• Ministry of Agriculture (MOA) • Agriculture Bureau • Regulatory Authority • Milk processors
Lack of proper cooling, storing and transporting systems • Limited milk chilling centres • Lack of suitable transportation system • Limited cold chain transportation	• Enforcing regulations to ensure the safe and high-quality production of milk • Giving training • Avail cold chain transportation • Abide to milk transportation rules & regulations • Strengthen regulatory systems	• Milk collectors • Milk processors • Agricultural Offices • Regulatory Authority
Lack of strong regulatory systems • Lack of comprehensive regulations • Limited enforcement capacity • Inadequate infrastructure • Limited testing and quality control capabilities • Limited skill and knowledge on implementation of Good Hygienic practices • Absence of milk check points	• Implementing comprehensive regulations (Establish regulatory office at lower level administration) • Improving testing and quality control capabilities • Strengthening enforcement capacity • Investing in infrastructure development • Establish systems of capacity building, research and inculcation to maintain quality standards and competitiveness • Establish milk quality check points at strategic locations • Stuffing with skilled man power	• Federal and Regional Authorities for regulatory of Agricultural Inputs and Products • Research institutions • Universities • Agricultural Offices
Mandate overlapping of Agriculture Office and Regulatory Authority	• Establish clear mandate of Agri. & Regulatory offices	•President council •Agricultural Inputs & Product Regulatory Authority
Absence of regulatory structure at lower administration levels & weak implementation of rules & regulations	• Establish regulatory structure at zonal & district level • Implement rule & regulation of milk quality control at lower level of administration • Control implementation of rule & regulation	•Regulatory Authority •Legal offices

Conclusions

The physical qualities of raw milk (specific gravity, water content and freezing point) in the study milk sheds were found within the normal quality range of raw milk set by the Ethiopian Standard Institute indicating that adulteration of milk with water is not a common problem in the areas. Milk produced under farmers condition may not be timely collected or it may not be collected in appropriate milk collection and transportation facilities. This is confirmed by the lower pH and higher titratable acidity values of raw milk sampled from the study milk sheds. The lower pH and higher titratable acidity ranges of raw milk could also be related to poor milk handling, lack of cooling facilities and poor and long storage practices of milk used by collectors, retailers, and consumers that might have resulted in higher bacterial growth of milk in the areas. Except the fat content, all chemical composition of raw milk in the study milk sheds are within the normal range of raw cow milk set by the Institute of Ethiopian Standard.

Significantly higher total bacterial count (7.23log10cfu/ml) was recorded for milk samples collected from retailers while the lowest TBC ($6.46^{b}\pm0.14$) was from milk samples collected from producers. Significantly higher CC were observed in milk samples collected from retailers ($5.43^{a}\pm0.10$ log10 cfu/ml) and consumers (5.47 ± 0.10 log10 cfu/ml) indicating that CC increases along the value chains which could be related to poor environmental hygiene, poor hygienic milking practices and further handling. These substandard microbial quality of milk in the study milk sheds are attributed to factors like unhygienic milking practices used by the farmers, shortage of clean water, lack of quality feed and feeding practices, health of animal, adulteration of milk, inappropriate milk storage and transportation systems, absence of standard milk equipment and basic requirements for milk collection, market problems, unhealthy competition of milk collectors and lack of milk regulatory systems reported in the areas. Capacitating stakeholders involving in milk production, collection and marketing through skill training, improving the supply clean water, controlling feed quality and feeding practices, improving animal health services, creating market linkages and enforcing milk regulatory systems are suggested to enhance the quality of milk in the study milk sheds.

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