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Physicochemical Quality of Raw and Pasteurized Milk from Sebeta and Bishoftu Urban Areas, Oromia, Ethiopia

Dereje Shibru[1*], Berhan Tamir[1], Firew Kassa[2] and Gebeyehu Goshu[1]

[1]Addis Ababa University, College of Veterinary Medicine and Agriculture, Bishoftu, P.O. Box 34, Ethiopia

[2]Ethiopia Institute of Agriculture Research (EIAR), Holetta Agricultural Research Center, Ethiopia

[*]**Corresponding author:** Shibru D, Addis Ababa University, College of Veterinary Medicine and Agriculture, Bishoftu, P.O. Box 34, Ethiopia, E-mail: shibrud@gmail.com

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Abstract

The study was aimed at analyzing the physicochemical quality of raw and pasteurized milk of crossbred dairy cows from Sebeta and Bishoftu area of Oromia Regional State, Ethiopia. A total of a hundred raw milk and twelve pasteurized milk samples were used to analyze the physicochemical qualities. The General Linear Model (GLM) was utilized for variance analyses of data on milk physicochemical parameters. The difference in sample type significantly affected physical parameters of milk pH, specific gravity and freezing point. The results for the percentage overall raw milk sample of Sebeta and Bishoftu area showed that lactose (4.91 ± 0.12), protein (3.28 ± 0.08)%, fat (3.68 ± 0.25)%, solid not fat (8.93 ± 0.22)%,total solid (12.61 ± 0.41)%, ash (0.74 ± 0.02)% and lactose (4.36 ± 0.06)%, Protein (2.90 ± 0.04)%, fat (3.59 ± 0.13)%, solid not fat (7.93 ± 0.11)%, total solid (11.52 ± 0.20)%, ash (0.66 ± 0.01)% respectively. A significant difference was observed in lactose, protein, solid-non-fat, total solid and ash values between the study sites. Raw milk samples from Sebeta areas had a higher percentage of composition whereas physicochemical components of pasteurized milk were significantly lower than that of raw milk and also below the minimum requirement of Ethiopian standard for protein, fat, total solids and specific gravity. The results of this finding of raw milk fulfill minimum requirements of standards to be accepted. The finding of this study provided up to date information on raw and pasteurized milk physicochemical quality which can be an important input for regulatory bodies.

Keywords: Milk composition; Raw milk; Fat; Protein; Lactose; Solid-not-fat and Total solid; pH; Specific gravity; Freezing point

Introduction

The world's milk is predominantly produced from cows followed by buffalo milk [1]. Several factors including genetics, breed of animal, environment, stages of lactation, parity, and nutrition, together determine the final composition of milk [2]. According to COMESSA [3] milk is defined as the normal, clean and fresh secretion, without any addition or subtraction, extracted from the udder of a healthy cow, and free from colostrum. Apart from being important for the nutrition of the young, milk-borne biologically active compounds such as casein and whey proteins have been found to be increasingly important for physiological and biochemical functions that have crucial impacts on human metabolism and health [4]. These compounds have been found to be useful in guarding humans against pathogens and illnesses [5]. Milk is made up of a complex mixture of fats, proteins, carbohydrates, minerals, vitamins and other miscellaneous constituents dispersed in water [6]. The composition of cows' milk is of the greatest importance for the dairy industry, since, its process ability is highly influenced by composition. Moreover milk quality and safety are important consumer requirements [7]. Therefore knowing the physical parameters and composition of milk in conformity with consumer's requirements helps to assure the status of milk suitability either for milk processing industries or consumers. Enough studies have not been reported on the physicochemical composition of milk marketed in study areas. Therefore, in this study, investigation of various physical parameters and chemical components of available milk samples were collected to determine the condition of cow milk commonly used. The findings were also compared with Ethiopian quality standards and European quality standards.

Methods

Study sites

The study was conducted at Sebeta and Bishoftu towns in the central high lands of Ethiopia.

Sebeta Awas wereda: is located at a distance 25 km away in the south West of Addis Ababa in the Oromia Regional state. Sebeta town is its administrative center. The town is situated at latitude and longitude of 8°55′N 38°37′E and 8.917°N 38.617°E respectively. The average elevation of Sebeta town is 2405 m a.s.l. and temperature of 22°C.

Bishoftu town is located at a distance of 45 km South East of Addis Ababa, Ethiopia. The town is located in the east Showa zone of Oromia region at about 9° North latitude and 40° East longitude at an altitude of 1850 m above sea level in the central high land of Ethiopia. It has an annual rainfall of 866 mm of which 84% is in the long rainy season (June to September) and the remaining in the short rainy season extending from March to May. The dry season extends from October to February. The mean annual maximum minimum temperatures of the area are 26°C and 14°C respectively, with a mean relative humidity of 61.3%. The mixed farming system followed in the area, crop and livestock production is an intensive type of production. Cattle, small ruminant, poultry and equines are the major livestock species kept with fast-growing smallholder dairy production [8]. The total population of Ada`a district is 131,273 [9]. As information obtained from the district agricultural office revealed, the total livestock population of the district in 2007 was 291,539 of which both local and crossbred cows accounted for 11.68%. The area is certainly the most developed milk shed of the country, providing most of the dairy products available in the market of Addis Ababa, the largest and most diversified market of Ethiopia [10].

Sources of data and sampling techniques

The data sources of the study were dairy farms, milk collectors, milk and milk product market around the study area. Accordingly, all of the dairy farms, milk vendors and owners/workers of both the farms and vendors were supposed as sources of data. Raw, pasteurized milk and other milk product samples were collected from July 2017 to August 2018. Raw milk samples were collected from pooled containers of dairy farms and bulk tank containers of milk collectors. However, pasteurized milk samples were collected from shops and supermarkets. All the samples were collected using a random sampling method following the procedures below.

All samples were subsequently analyzed in the Dairy Laboratory of Holleta Agricultural research center.

Milk sample size determination and sample collection

A formula of Kothari [11] for unknown population (i.e. $n=Z2SD2/e^2$) was used to calculate the sample size for this study. Where Z, is the estimated standard variation at 95% Confidence Interval (CI) which will be considered the point of the normal distribution corresponding to the level of significance (Z=1.96). Standard deviation (SD) was estimated at 0.20 or 20% and e, is the estimated error and will be considered at 0.05 or 5%. Therefore, the sample size 'n' will be calculated as:

$$n=\frac{(1.96)^2\times(0.20)^2}{(0.05)^2}\approx 61.5 \text{ Approximately}$$

n=62 samples of milk and milk products were collected per each district while 62 samples of milk products will also be collected from market sources in Addis Ababa.

About 112 samples (that is 100 from raw milk and 12 from pasteurized) each containing 250 ml milk samples collected using sterile bottles and placed in an icebox as per the recommendations of IDF [12]. Raw milk samples were collected directly from pooled farm milk containers of the dairy farms (30 from Sebeta and 30 from Bishoftu) urban areas and bulk tank milk collectors' containers (20 from Sebeta and 20 from Bishoftu). A total of 12 samples of pasteurized milk were also collected from different branded pasteurized milk. About 250 ml of fresh raw milk samples were taken twice at different times aseptically from each dairy farm and milk vendor in two months interval. Similarly, 250 ml of pasteurized milk samples were taken twice at different times from similar dairy processing brands. After aseptically collecting the milk samples with sterile bottles, samples were transported to Holleta Agricultural Research Center Dairy Laboratory for Physicochemical analysis. Upon arrival at the laboratory, the milk samples were divided into two and used for the determination of physicochemical properties.

Milk composition analysis

Analyses for physicochemical properties of milk were performed at Holleta Agricultural Research Center Dairy Laboratory using a Lacto scan to determine the percentage composition density, freezing points, pH, lactose, protein, total fat, total solid and Ash. Percent Solids-not-fat was calculated by the following formulas: %SNF=%Total solids–% Fat.

Data management and statistical analysis

The data obtained was tabulated and analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System version 9.1 [13]. Mean separation were carried out using the Least Significant Difference (LSD) technique when analysis of variance (ANOVA) shows significant differences between means. Differences were considered statistically significant at 5, 1, and/or 0.1% significance level. The following models were used for the milk physicochemical data:

$$Y_{ijk}=\mu+\alpha_i+\beta_j+e_{ijk}$$

Where Y_{ijk}=individual observation for each sample

μ=the overall mean

α_i=the i^{th} milk and milk product sources sites effects (i.e Sebeta, Bishoftu, supermarket in Addi s Ababa)

β_j=the j^{th} milk and milk product sample type effect (raw milk, pasteurized milk)

e_{ij}=the error term.

Results and Discussion

Hydrogen ion concentration (pH)

The Mean ± (SEM) of the pH of milk sampled from the Sebeta and Bishoftu area is shown in **Table 1**. The milk collected from the Sebeta area had an average milk pH of 6.28, whereas the milk from the Bishoftu area had a pH of 6.49. Milk samples from the Bishoftu area farm pooled were significantly higher in pH than the other types of samples. Milk samples from the Bishoftu area were slightly below the required standard but of Sebeta area was more acidic. A similar study from the Shashamene area reported pH value better than Sebeta and almost similar to Bishoftu's area farm pooled type of this study [14]. According to East African Standards, the recommended raw cow milk pH is 6.6 to 6.8 which can withstand the boiling temperature [15]. There are many factors that can make the raw cow milk acidic, but the major one is poor storage under room temperature which accelerates microbial activities on lactose to be converted to lactic acid [16]. Sometimes, low pH of milk may be due to the presence of high levels of casein, acid phosphates, and citrates and carbon dioxide [17,18].

Specific gravity

The Mean ± (SEM) of the specific gravity of milk sampled from the Sebeta and Bishoftu area is shown in **Table 1**. There was a significant difference ($p<0.001$) in specific gravity among the study areas and the value of specific gravity in general falls within the ranges of Ethiopian Standard (ES) value but pasteurized milk was significantly lower in specific gravity than the raw milk and lower than the standard **(Table 1)**. Sebeta areas sample of bulk tank milk (1.033+0.02) was significantly higher than the other and out of the standards [19]. A similar finding was reported from Shashamene for milk collected from small scale milk producers and dairy cooperative milk collection centers [14]. More similar results of 1.030 were reported from on-farm study results [20]. Opposing these results below 1.026 of specific gravity was also reported from Dairy Farms in Pemba Island Zanzibar of Tanzania [21].

Freezing point

The Mean ± (SEM) freezing point of milk sampled from Sebeta and Bishoftu area is shown in **Table 1**. In this study, relatively the freezing point of the Sebeta area (-0.619°C) milk was significantly ($p<0.01$) lower than that of the Bishoftu area (-0.486°C) **Table 1**. The freezing point of milk is determined primarily either to prove milk adulteration with water or to determine the amount of water added [22]. Similarly, the freezing point of milk is used as one of the quality criteria for insuring high-quality milk [23]. There might be adulterations of solutes in Sebeta area milk samples whereas water adulteration in milk might be high in Bishoftu area samples. The figures of these findings, particularly of Sebeta samples, were found to be out of the ranges of average reported milk freezing point -0.540°C [19,24].

Table 1: Mean ± (SEM) raw and pasteurized milk preliminary quality tests of Sebeta and Bishoftu areas.

Study sites	N	Sp. gravity	Freezing pt.	pH
Sebeta				
Farm pooled	30	1.029b ± 0.000	-0.528b ± 0.008	6.28b ± 0.07
Bulk tank	20	1.033a ± 0.002	-0.619a ± 0.024	6.28b ± 0.04
Bishoftu				
Farm pooled	30	1.028bc ± 0.00	-0.525b ± 0.005	6.56a ± 0.05
Bulk tank	20	1.026c ± 0.001	-0.486b ± 0.012	6.31b ± 0.02
Pasteurized	12	1.023d ± 0.001	-0.422c ± 0.023	6.01c ± 0.41
Significance		***	***	***

*=p<0.05; **=p<0.01; ***=p<0.001; NS=Non-Significant; LS Mean=Least Square Mean; SE=Standard Error; a,b,c,d: means in the same column with different subscript letters were significantly different

Lactose percentage of milk samples

The overall lactose percent of milk sampled from the Sebeta and Bishoftu area is shown in **Table 2**. The lactose percentage of milk sampled from the Sebeta area (4.91 ± 0.12) was higher than that of Bishoftu areas (4.36 ± 0.06) **(Table 2)**. Milk sampled from the sebeta area was significantly higher for lactose percent than Bishiftu areas and pasteurized milk samples. Earlier reports for lactose content (4.24%) showed lower results than percent of lactose with that of Sebeta areas whereas comparable with the current study result of the Bishoftu area [25]. A similar study result from the Shashamene area reported that the overall lactose percent of 4.43+0.06 which is almost similar to that of the Bishoftu area but less than that of the Sebeta Area finding [14]. The result of this study is greater than that of the overall Lactose% value (4.28 ± 0.08%) reported from Amanuel Town of Ethiopia [26].

The protein percentage of milk samples

The overall Protein percent composition of milk sampled from the Sebeta and Bishoftu area is shown in **Table 2**. The protein percentage of milk sampled from the Sebeta area (3.28 ± 0.08) was higher than that of Bishoftu areas (2.90 ± 0.04) **(Table 2)**. There was a significant difference in protein %, values between the study areas and milk samples ($p<0.01$) with a higher percentage record from Sebeta areas. Milk sampled from the bulk tank of the Sebeta area has the highest protein percent and lowest record of protein percent for milk recorded for pasteurized milk. The overall values of this study for protein% sampled from Sebeta areas agree with Ethiopian standard values (3.2%) but higher than that of European Union quality standards (2.73%). Protein percent of milk sampled from Bishoftu areas was less than values (3.2%) of Ethiopian standard but higher than that of European Union quality standards [19]. Almost a similar figure with the current finding of the Sebeta Area was reported by Dehinenet G et al. where protein percentage was 3.12 ± 0.32 of milk samples from the Godino and Babogaya [27]. The previous study reported a higher value of 5.61% protein for Borana × Friesian from the Holetta area [28]. The results of this study is greater than that of the overall protein percent values (2.83 ± 0.06%) reported [26] from Amanuel Town of Ethiopia.

The fat percentage of examined milk samples

The overall Fat percent composition of milk sampled from the Sebeta and Bishoftu area is shown in **Table 2**. The fat percentage of milk sampled from the Sebeta area (3.68 ± 0.25) was higher than that of Bishoftu areas (3.59 ± 0.13) **(Table 2)**. The overall values of this study for Fat % sampled from Sebeta areas higher than that of Ethiopian standard values (3.5%) and European Union (EU) quality standards (3.25%) [19]. But for Bishoftu areas almost similar to that of Ethiopian standard values (3.5%) and but higher than that of European Union quality standards (3.25%) [19]. However, it is less than the finding of Asaminew Tassew, who reported 4.14 fat percent for crossbred cows' milk from Bahir Dar milk shed [29]. Greater result (4.12 ± 0.26%) for the overall average value of fat was reported by Desyibelew W and Wondifraw Z from Amanuel Town of Ethiopia [27].

Solids not fat (SNF) percentage of examined milk samples

The overall Solid Not Fat percent composition of milk sampled from the Sebeta and Bishoftu area is shown in **Table 2**. The solid Non-Fat percentage composition of milk sampled from the Sebeta area (8.93 ± 0.22) was higher than that of Bishoftu areas (7.93 ± 0.11). The overall values of this study for SNF% sampled from Sebeta areas (8.93 ± 0.22) were higher than that of the Bishoftu area (7.93 ± 0.11) and European Union (EU) quality standards (8.25%) [19]. But milk sampled from the Bishoftu area was less than that of the European Union (EU) quality standards (8.25%) [19]. Comparable results with the Sebeta area were also reported by Dehinenet G et al. [27] for solid not fat percentage (8.88 ± 0.83) of milk samples from the Godino and Babogaya. Higher SNF results than the current one were also reported by Helen Nigussie for SNF contents (10.7%) for cows' milk in Kombolcha woreda [30]. In addition, the previous study by Desyibelew W and Wondifraw Z (2019) also reported almost similar results to the current study for SNF (7.77 ± 0.14%) from Amanuel Town of Ethiopia [26].

Milk total solids percentage of examined milk samples

The overall Total solid percent of milk sampled from the Sebeta and Bishoftu area is shown in **Table 2**. The total solid percentage composition of milk sampled from the Sebeta area (12.61 ± 0.41) was higher than that of Bishoftu areas (11.52 ± 0.20). The overall values of this study for Total solid % sampled from Sebeta areas were less than the Ethiopian standard values (12.8%) but it was in agreement with European Union (EU) quality standards (12.5%) [19]. But the sample result obtained from the Bishoftu area was less than both quality standards. Higher than the current study results were reported [31] in the Sebeta area where the overall percentage composition of total solids (12.92+1.6). The overall mean TS of Sebeta (12.61%) and Bishoftu (11.52%) content obtained in this study is lower than earlier findings of [32] and [33] that reported 13.55% and 14.31% for Boran and Horro cows' milk, respectively. Another report [26] for TS% (11.89 ± 0.40) also showed greater results than that of the Bishoftu area finding but less than of Sebeta's finding of this study.

Total ash percentage of milk

The overall Ash percent composition of milk sampled from the Sebeta and Bishoftu area is shown in **Table 2**. The total Ash percentage composition of milk sampled from the Sebeta area (0.74 ± 0.02) was higher than that of Bishoftu areas (0.66 ± 0.02). Less than the current finding for total ash (0.59%) was reported in our earlier study from Sebeta area [31]. The ash content (0.74%) obtained in the current study of Sebeta area is comparable with the findings of Derese Teressa [32] and Asaminew Tassew [29] who reported ash content of 0.73% and 0.74% for the milk sampled from Bahir Dar milk shed and west Shoa areas. However, the overall mean ash content obtained in this study from the Bishoft area is lower than the findings of Derese Teressa [32] and Asaminew Tassew [29]. The ash% (0.63 ± 0.01) reported by Desyibelew W and Wondifraw Z in agreement with the Bishoftu area of this study but less than that of Sebeta areas result of this study [26].

Percentages of the physicochemical composition of pasteurized milk

The overall percent chemical composition of milk sampled from pasteurized milk from Addis Ababa supermarkets and shops is shown in **Table 2**. Pasteurized milk was significantly lower in milk composition for lactose, protein, Solid Non-Fat (SNF), Total solid and ash values than the raw milk sampled from the Bishoftu and Sebeta area of this study. The specific gravity of this study for pasteurized milk (1.023 ± 0.001) was

far below than Ethiopian Standard (1.026 to 1.032) [19]. The freezing points of this study (-0.422+0.023) were within the range of the standard [19] value (0.525 to 0.550). pH value (6.01+0.41) of this study is similar to the study results reported by Zelalem Yilma, which was pH value ranged from the lowest 5.46 to the highest 6.14 with an overall mean value of 5.87 [34]. The previous findings for the overall value of protein (2.57%) and fat (3.05%) is similar to the current study finding. But the current study result for overall Total solid (9.78+0.47) is far below the finding of Zelalem for Total Solids (11.10) [34]. The result of this study was not conforming to the minimum requirement of the Ethiopian standard (ES) for protein (3.20%) and whole milk fat (3.5%).

Table 2: Mean ± (SEM) raw and pasteurized milk composition content of Sebeta and Bishoftu areas.

Study sites	N	Lactose	Protein	Fat	SNF	TS	Ash
Sebeta							
Farm pooled	30	$4.57^{b} \pm 0.06$	$3.05^{b} \pm 0.04$	$3.50^{ab} \pm 0.23$	$8.31^{b} \pm 0.11$	$11.81^{b} \pm 0.26$	$0.69^{b} \pm 0.01$
Bulk tank	20	$5.25^{a} \pm 0.18$	$3.50^{a} \pm 0.12$	$3.86^{a} \pm 0.27$	$9.54^{a} \pm 0.33$	$13.40^{a} \pm 0.56$	$0.79^{a} \pm 0.03$
Overall seb.	**50**	**4.91 ± 0.12**	**3.28 ± 0.08**	**3.68 ± 0.25**	**8.93 ± 0.22**	**12.61 ± 0.41**	**0.74 ± 0.02**
Bishoftu							
Farm pooled	30	$4.51^{bc} \pm 0.03$	$3.00^{bc} \pm 0.02$	$3.49^{ab} \pm 0.11$	$8.21^{bc} \pm 0.05$	$11.70^{b} \pm 0.13$	$0.68b^{c} \pm 0.00$
Bulk tank	20	$4.21^{c} \pm 0.09$	$2.80^{c} \pm 0.06$	$3.69^{ab} \pm 0.15$	$7.65^{c} \pm 0.16$	$11.34^{b} \pm 0.27$	$0.63^{c} \pm 0.01$
Overall Bish.	**50**	**4.36 ± 0.06**	**2.90 ± 0.04**	**3.59 ± 0.13**	**7.93 ± 0.11**	**11.52 ± 0.20**	**0.66 ± 0.01**
Pasteurized	12	$3.72^{d} \pm 0.19$	$2.48^{d} \pm 0.12$	$3.01^{b} \pm 0.15$	$6.77^{d} \pm 0.33$	$9.78^{c} \pm 0.47$	$0.56^{d} \pm 0.03$
Significance		***	***	NS	***	***	***

*=p<0.05; **=p<0.01; ***=p<0.001; NS=Non Significant; LS mean=Least Square mean; SE=Standard Error; a,b,c,d: means in the same column with different subscript letters were significantly different

Correlation coefficients among the different milk quality parameters

The overall correlation between the physicochemical components of raw milk sampled from Sebeta and Bishoftu town is shown in **Table 3**. Protein content was strongly correlated with ash, SNF, lactose, total solids, specific gravity and freezing point of milk. This correlation appears positive and confirms the rule that the higher protein values, the higher the other components. The fat content of milk was weakly correlated with protein, Ash, SNF, lactose, specific gravity, total solid and freezing point of milk. The specific gravity of milk was strongly correlated with protein, ash, SNF, lactose, total solid and freezing point of milk.

Table 3: Correlation between physico-chemical properties of raw milk in the study areas.

Variable	Total Solid	Protein	Fat	Ash	SNF	Lactose	pH	Sp. Gravity	Frezg pt.
Total solid	1								
Protein	0.830^{***}	1							
Fat	0.820^{***}	0.357^{**}	1						
Ash	0.830^{***}	0.996^{***}	0.367^{**}	1					
SNF	0.830^{***}	0.9980^{***}	0.359^{**}	0.994^{***}	1				
Lactose	0.830^{***}	0.999^{***}	0.364^{**}	0.996^{***}	0.998^{***}	1			
pH	0.086^{NS}	0.012^{NS}	0.123^{NS}	0.083^{***}	0.021^{NS}	0.014^{NS}	1		
Specific Gravity	0.834^{***}	0.999^{***}	0.364^{**}	0.996^{***}	0.998^{***}	0.999^{***}	0.014^{NS}	1	
Freezing pt.	0.864^{***}	0.988^{***}	0.423^{***}	0.984^{***}	0.989^{***}	0.999^{***}	0.033^{NS}	0.988^{***}	1

**Correlation is significant at the 0.001 level (2-tailed); ***Correlation is significant at the 0.0001 level (2 tailed); NS: have no significant difference correlation

Conclusion

In the present study, investigations were carried out to ascertain the physicochemical qualities of various milk samples marketed in Sebeta and Bishoftu areas. Milk sampled from Sebeta areas showed significantly higher percentage for fat, Solid Non Fat (SNF), Total solid and ash values than that of Bishoftu. The overall mean value of milk composition in the study area is almost similar/within the range of/to Ethiopian standard value.

There was also a significant difference in the percentage of lactose, protein, Solid Non-Fat (SNF), and Total solid and Ash% values between the study areas and milk samples with the higher percentage component from Sebeta areas. The overall values for protein from this study area agree with Ethiopian standard values, whereas the percentage of total solid and SNF is slightly lower than Ethiopian standard values. In general, this finding may be helpful for the concerned governmental parties to monitor the quality of the milk products in the market of Central Ethiopia. Moreover, it is to date an overview of the physicochemical quality status of milk for collectors, dairy factories and consumers about study sites.

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