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Location, Season and Source Effects on Gross Composition of Raw Cow's Milk Across Khartoum State, Sudan

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Abstract

This study was conducted to investigate the effect of sources. locations and seasons (late summer and winter) on the chemical composition of cow milk collected from Khartoum State. The samples were collected randomly in the morning or the evening. Two hundred and seventy milk samples were collected from farms (90 samples), groceries (90 samples) and vendors (90 samples) in Khartoum State during the late summer and winter seasons, 135 samples each. The milk samples were kept in cool cracked ice and transported immediately to the laboratory to estimate the gross compositional contents. The experiment was designed using a complete randomized design, and the data were analyzed using the SPSS program. The results indicated significant ($P \leq 0.01$) variations for the chemical composition of the raw cow's milk collected during late summer and winter seasons as the data showed 12.44% ±

1.23% and 11.95% ± 1.70% total solids, 4.56% ± 1.02% and 4.79% ± 1.14% fat and 3.28% ± 0.79% and 3.67% ± 0.51% protein, respectively. Also, the average means of fat, protein and ash content were significantly ($P \leq 0.01$) affected by the locations from which the samples were obtained. The higher average fat content (4.93 ± 1.04%) was found in the milk collected from Omdurman city. However, the total solids content of the milk samples collected from different sources, including farms, groceries, and vendors, were not significantly ($P > 0.05$) different. The present data showed that the chemical compositions of milk were significantly ($P < 0.01$) affected by the interaction of seasons and the sources of the samples as well as between the seasons and locations. Moreover, the milk produced and marketed in Khartoum State has a good compositional content that ranges within the standard values.

Keywords
Cow milk; chemical composition; late summer; winter; farms; vendors; Khartoum state

1. Introduction

Milk is the normal mammary secretion, excluding colostrum, from one or more healthy animals and comprises composition like ash, fat, lactose, protein, and total solids [1]. Also, milk is enriched in nutritional aspects like proteins, fats, sugars, minerals, and vitamins that support the life and health of living entities [2]. Milk/dairy foods supply key nutrients, particularly at certain life stages [3]. Moreover, over the past thirty years, milk product diets around the globe have provided nutritional benefits to cater to the increased population consumption/production [4].

Among the factors affecting the milk composition of dairy cows include diet and feeding, inheritance, days in milk, number of lactations, disease conditions, and seasonal humidity and temperature [5]. Nutrition may well influence the sources of variation in the composition/yield of milk, along with climatic conditions, seasonal variation and regional differences [6]. Genetic factors greatly influence milk production as the specialized breeds produce more milk, with an inverse relation between total solids, fat, and protein and milk produced [7]. Overall, milk samples from dairy cows in Ethiopian farms would average 2.68 ± 1.73% fat, 3.17 ± 0.24% protein, and 4.76 ± 0.36% lactose contents by lactation stage, breed, parity, herd size, and altitude [8].

Milk quality and composition are key to the dairy industry and human health and directly relevant to processability [6]. Humans consume domesticated animals' milk frequently, either as fluid or after being processed into various dairy products [9]. Thus, understanding the milk composition essential to the dairy industry could influence the nutritional value and processing characteristics alongside their functional properties [10]. Milk composition (fat, protein, and lactose content) could be positively influenced by seasons [11]. Bovine milk comprises 3%-4% fat, 4-5% lactose, 3% protein, 0.8% minerals, and 0.1% vitamins, despite water content 87% [12, 13]. At the average freezing point, the solid-not-fat and protein content would be higher in warm seasons, while the average acidity, lactose, and fat content were higher in cold seasons [14]. In Greece, the season could significantly influence the protein, ash, and added water content of retail cow's milk [15]. Milk obtained in the spring/summer season generally showed a significantly lower content of fat and protein [16]. However, the milk during the summer season in Tunisia contained more fat [17]. Meanwhile, Warsma *et al.* [18] reported significantly (P ≤ 0.001) higher content of fat (5.03%) and SNF (11.52%) for the cows' milk samples tested during Sudan's winter, while highly significant (P ≤ 0.001) values during summer for lactose (4.72%) and acidity (0.19%). Regardless of the animal group, the fat content in bulk milk was significantly lower in summer compared to other seasons, despite peaks being realized in winter [19]. Additionally, the season would reflect the availability of forage and the type of grazing system [7]. To justify the need for the current work, it was hypothesized that raw cow milk is essential through human nutrition/technological characteristics. To supplement existing information, the current study investigated the location, season, and source effects on the gross composition of raw cow milk across Khartoum State, Sudan. Specifically, the seasons involved late summer and winter, and different sources involved farms, groceries, and vendors.

2. Materials and Methods

2.1 Study Area

Khartoum State, which is located in central Sudan, lays in the semi-arid zone between the latitude 15.08-16.39°N and longitude 31.36-34.25°E. The state consists of the 3 main cities that include Khartoum, Khartoum North and Omdurman. Khartoum State is ranked first in the milk production in Sudan and the cows' milk represents about 65% of the produced and consumed milk.

2.2 Source and Collection of Milk Samples

This investigation was based on collecting raw milk samples from farms in the 3 main cities of Khartoum State (Khartoum, Khartoum North and Omdurman). About 270 milk samples were included in this study; 135 samples during late summer (June-July, 2016) and 135 samples during winter (October-December). The milk samples were collected from Khartoum (90 samples), Khartoum North (90 samples) and Omdurman (90 samples); 45 samples were examined during each season from groceries, farms and vendors in each town (15 samples from each source). The milk samples were collected into clean sterile bottles and transported to the laboratory of the Department of Dairy Production, University of Khartoum, where the examination of the milk samples was conducted.

2.3 Examination of Milk Samples

The total solids and ash content of cows' milk samples were examined using the standard methods as described in the AOAC [20]. Meanwhile, the fat and protein content were obtained directly using Lacto-scan milk analyzer [21].

2.3.1 Total Solids Content

The total solids content of milk samples was determined according to the method of AOAC [20]. About 5 ml of each milk sample was placed separately in a clean dried aluminum dish. The weight of the sample and the dish were recorded and heated in a steam bath at 37°C for 10 minutes. The dishes were then heated in an oven at 100°C for 3 hours, followed by cooling in a desiccator and weighing quickly until a constant weight was obtained. Heating, cooling, and weighing were repeated several times until the difference between two successive weightings was less than 0.5 mg. The total solids content was calculated as follows:

$$T.S(\%) = W_1/W_0 \times 100$$

W_1 = Weight of sample after drying.
W_0 = Weight of sample before drying.

2.3.2 Fat and Protein Contents

The milk samples were analyzed for fat and protein by using the Lacto-scan milk analyzer (Milko-tronic LTD, Nova Zagora, Bulgaria) according to the manufacture' instructions. First, each milk sample (duplicate) was mixed gently about 4-5 times to avoid any air enclosure in the milk to be tested. Then, 5 ml of the milk samples were taken in a sample holder, one at a time, and put in the sample holder with the analyzer in the recess position. After the starting button was inactivated and the analyzer sucked the milk, the measurements that appeared in the digital display were taken as a reading result [21].

2.3.3 Ash Content

The ash content of milk samples was determined as described in AOAC [20], using a muffle furnace. About 5 ml of the milk samples were weighed in suitable crucibles and evaporated to dryness in a steam bath. The sample was placed in a muffle furnace (550°C) for 3 hours, then cooled in a desiccator and weighed. The ash content was calculated using the following equation:

$$Ash(\%) = W_1/W_0 \times 100$$

Where:
W_1 = Weight of ash residues.
W_0 = Weight of sample.

For the evaluation of analytical method validation, the precision of the results was evaluated by the standard deviation of the triplicate samples that were analyzed under the same conditions. Most of the results showed that the method is very accurate and valid for determining studied parameters.

2.4 Statistical Analysis

The statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 16 [22]. The General Linear Model (GLM) was used to determine the variation effects across different sources and locations, comparing late summer and winter seasons. Means were separated using the least significant difference (LSD) at a significant level of $P \leq 0.05$.

3. Results

3.1 Gross Milk Composition by Seasons

Gross cow milk composition by seasons (late summer and winter) is shown in Table 1. The mean total solids content during the late summer season (12.44 ± 1.23%) was significantly ($P < 0.001$) higher than those of the winter season (11.95 ± 1.70%). The mean fat content of milk samples collected during the winter season (4.79 ± 1.14%) was significantly ($P < 0.05$) higher than those collected during the late summer season (4.56 ± 1.02%). The mean protein content of samples collected during the winter season (3.67 ± 0.51%) was significantly ($P < 0.001$) higher than those collected during the late summer season (3.28 ± 0.79%). The mean ash content of milk samples collected during the winter and late summer seasons revealed 0.82 ± 0.26% and 0.81 ± 0.23% respectively, with much resemblance ($P > 0.05$).

Table 1 Gross cow milk composition by seasons (late summer and winter).

Gross milk composition (%)	Seasons		Significant Level
	Late summer	Winter	
Total solids	$12.44^{b} \pm 1.23$	$11.95^{a} \pm 1.70$	***
Fat	$4.56^{a} \pm 1.02$	$4.79^{b} \pm 1.14$	*
Protein	$3.28^{a} \pm 0.79$	$3.67^{c} \pm 0.51$	***
Ash	$0.81^{a} \pm 0.23$	$0.82^{a} \pm 0.26$	NS

Means in each row bearing the same superscript a, b, letters are not significantly different ($P > 0.05$).

NS = Non significant.

* = $P \leq 0.05$.

*** = $P \leq 0.001$.

3.2 Gross Milk Composition by Different Locations

Table 2 shows the gross milk composition by different locations (Khartoum, Khartoum North, and Omdurman cities). The mean total solids content was significantly ($P < 0.05$) higher in the milk collected from Khartoum North (12.30 ± 1.18%) and lower than those from Omdurman (12.02 ± 0.82%). Similarly, the location showed a significant ($P < 0.01$) effect by the milk fat content and samples from Omdurman, Khartoum North and Khartoum were 4.93 ± 1.04%, 4.85 ± 1.21% and 4.59 ± 0.98%, respectively. Table 2 also showed mean protein content of milk samples was significantly ($P < 0.01$) higher at Omdurman (3.66 ± 0.59%) compared to those of Khartoum (3.53 ± 0.57%) and Khartoum North (3.53 ± 0.81%). The mean ash content of milk samples from Khartoum (0.87 ± 0.28%) was significantly ($P < 0.01$) higher than those collected from Khartoum North (0.80 ± 0.26%) and Omdurman (0.79 ± 0.21%) (Table 2).

Table 2 Gross milk composition by location across Khartoum State.

Milk composition (%)	Locations			Significant Level
	Khartoum	Khartoum North	Omdurman	
Total solids	$12.22^{ab} \pm 1.05$	$12.30^{a} \pm 1.18$	$12.02^{b} \pm 0.82$	*
Fat	$4.59^{b} \pm 0.98$	$4.85^{a} \pm 1.21$	$4.93^{a} \pm 1.04$	**
Protein	$3.53^{b} \pm 0.57$	$3.53^{b} \pm 0.81$	$3.66^{a} \pm 0.59$	**
Ash	$0.87^{a} \pm 0.28$	$0.80^{b} \pm 0.26$	$0.79^{b} \pm 0.21$	**

Means in each row bearing the same superscript a, b letters are not significantly different (P > 0.05).
* = P ≤ 0.05.
** = P ≤ 0.01.

3.3 Gross Milk Composition by Sources in Khartoum State

The gross milk composition by the sources (farms, groceries and vendors) is shown in Table 3. The milk still had permanently high mean total solids contents, although revealed non-significant (P > 0.05) in farms (12.25 ± 1.21%), followed by vendors' milk (12.22 ± 1.01%) and groceries (12.14 ± 0.85%). However, the mean fat content of milk samples was significantly (P < 0.01) by different sources, being higher from the farms (5.36 ± 1.04%) compared to those purchased from groceries (4.28 ± 1.05%) and vendors (4.27 ± 0.90%). Similarly, the mean protein content of milk samples collected from vendors (3.65 ± 0.89%) was significantly (P < 0.01) higher than those from the farms (3.47 ± 0.89%) and groceries (3.52 ± 0.51%). Meanwhile, the mean ash content was significantly (P < 0.01) higher at vendors (0.89 ± 28%), followed by milk from groceries (0.81 ± 0.23%) and farms (0.76 ± 0.21%).

Table 3 Gross milk composition by different sources.

Milk composition (%)	Source			Significant level
	Farms	Groceries	Vendors	
Total solids	$12.25^{a} \pm 1.21$	$12.14^{a} \pm 0.85$	$12.22^{a} \pm 1.01$	NS
Fat	$5.36^{a} \pm 1.04$	$4.28^{c} \pm 1.05$	$4.27^{b} \pm 0.90$	**
Protein	$3.47^{b} \pm 0.89$	$3.52^{b} \pm 0.51$	$3.65^{a} \pm 0.89$	**
Ash	$0.76^{a} \pm 0.21$	$0.81^{a} \pm 0.23$	$0.89^{b} \pm 0.28$	**

Means in each row bearing the same superscript a, b letters are not significantly different (P > 0.05).
NS = Non significant.
** = P ≤ 0.01.

3.4 Seasons - Locations Effect on Gross Milk Composition

Table 4 showed season - location effects on milk total solids content from Khartoum city during the winter season (12.65 ± 1.38%) was significantly (P < 0.01) higher compared to the milk samples collected from Omdurman city during the winter season (11.89 ± 0.64%). However, the mean fat content of those collected from Omdurman city during the winter season (5.27 ± 1.03%) was significantly (P < 0.01) high, while those collected from Khartoum city during the late summer season showed the lowest value (4.54 ± 1.17%). Similarly, the mean protein content of the samples collected from Omdurman city during the winter season (3.97 ± 0.51%) was significantly (P < 0.01) higher compared to those collected from Khartoum city during the winter season (3.34 ± 0.81%). However, the mean ash content of those collected from Khartoum city during the late summer season (0.88 ± 0.22%) was significantly (P < 0.05) higher than those collected from Khartoum North city during the late summer season (0.77 ± 0.23%) (Table 4).

Table 4 Season - location effects on gross milk composition across Khartoum State.

Location	Season	Gross milk composition (%)			
		Total solids	Fat	Protein	Ash
Khartoum	Late summer	12.46 ± 1.21^{a}	4.54 ± 1.17^{b}	3.44 ± 0.54^{bc}	0.88 ± 0.22^{a}
	Winter	12.65 ± 1.38^{a}	5.09 ± 1.23^{a}	3.34 ± 0.81^{c}	0.79 ± 0.23^{b}
Khartoum North	Late summer	12.16 ± 0.97^{b}	4.58 ± 0.88^{b}	3.36 ± 0.38^{c}	0.77 ± 0.23^{b}
	Winter	11.98 ±0.72^{b}	4.63 ± 0.86^{b}	3.60 ± 0.44^{b}	0.85 ± 0.31^{ab}
Omdurman	Late summer	11.95 ± 0.72^{b}	4.60 ± 1.31^{b}	3.58 ± 0.41^{b}	0.81 ± 0.27^{ab}
	Winter	11.89 ± 0.64^{b}	5.27 ± 1.03^{a}	3.97 ± 0.51^{a}	0.80 ± 0.20^{b}
Significant Level		**	**	**	*

Means in each row bearing the same superscript a, b, c letters are not significantly different (P > 0.05).

* = P ≤ 0.05.

** = P ≤ 0.01.

3.5 Season - Source Effect on Gross Milk Composition

Table 5 showed that gross milk composition had significant (P < 0.01) sources - season effects. The mean total solids are significantly higher comparing farms (12.51 ± 1.49%) during the late summer season, groceries (11.80 ± 0.68%) and vendors (12.03 ± 0.72%) during the winter season. The mean fat content of milk samples from the farms during the late summer season was significantly higher (5.54 ± 1.20%) compared to those collected from vendors (4.95 ± 0.95%) and groceries (4.39 ± 1.25%) during the winter season. Meanwhile, the mean protein content of milk samples was higher from vendors (3.90 ± 0.47%) during the winter season compared to those collected from the farms (3.35 ± 0.89%) and groceries (3.39 ± 0.45%). However, the mean ash content of milk samples was significantly higher (0.92 ± 0.29%) and more from vendors during the late summer season compared to those from the groceries (0.85 ± 0.30%) and farms (0.74 ± 0.19%) during the winter season (Table 5).

Table 5 Season - source effects on gross milk composition.

Season	Milk source	Gross milk composition (%)			
		Total solids	Fat	Protein	Ash
Late summer	Farms	12.51 ± 1.49^{a}	5.54 ± 1.20^{a}	3.35 ± 0.89^{c}	0.77 ± 0.21^{b}
	Groceries	12.35 ± 0.96^{a}	4.18 ± 0.83^{d}	3.39 ± 0.45^{c}	0.76 ± 0.14^{b}
	Vendors	12.41 ± 1.14^{a}	4.50 ± 0.84^{c}	3.41 ± 0.33^{c}	0.92 ± 0.29^{a}

	Farms	12.00 ± 0.66^{b}	5.17 ± 1.01^{b}	3.60 ± 0.44^{b}	0.74 ± 0.19^{b}
Winter	Groceries	11.80 ± 0.68^{b}	4.39 ± 1.25^{cd}	3.66 ± 0.50^{b}	0.85 ± 0.30^{a}
	Vendors	12.03 ± 0.72^{b}	4.95 ± 0.95^{b}	3.90 ± 0.47^{a}	0.87 ± 0.28^{a}
Significant Level		**	**	**	**

Means in each row bearing the same superscript a, b, c letters are not significantly different (P > 0.05).
** = P ≤ 0.01.

3.6 Location - Source Effect on Gross Milk Composition

Milk samples collected from vendors in Khartoum (Table 6) were significantly (P < 0.01) higher in total solids (12.46 ± 1.20%) compared to those from the groceries in Khartoum (11.88 ± 0.71%). However, the mean fat content of milk samples obtained from farms in Khartoum North (5.56 ± 1.23%) was significantly (P < 0.01) higher compared to those from groceries in Khartoum (3.99 ± 0.59%) (Table 6). The mean protein content of those from vendors in Omdurman (3.88 ± 0.55%) was significantly (P < 0.01) higher compared to those from groceries in Khartoum (3.29 ± 0.36%). The mean ash content (Table 6) for the milk samples collected from vendors in Khartoum (1.03 ± 0.29%) was significantly (P < 0.01) higher compared to those from the farms located in Omdurman (0.71 ± 0.19%).

Table 6 Location - source effect on gross milk composition.

Location	Milk source	Gross milk composition (%)			
		Total solids	Fat	Protein	Ash
	Farms	12.32 ± 1.01^{ab}	5.34 ± 1.10^{ab}	3.61 ± 0.65^{bc}	0.74 ± 0.18^{cd}
Khartoum	Groceries	11.88 ± 0.71^{c}	3.99 ± 0.59^{d}	3.29 ± 0.36^{d}	0.84 ± 0.25^{b}
	Vendors	12.46 ± 1.20^{a}	4.42 ± 0.79^{c}	3.68 ± 0.33^{ab}	1.03 ± 0.29^{a}
	Farms	12.46 ± 1.58^{a}	5.56 ± 1.23^{a}	3.52 ± 0.93^{bc}	0.81 ± 0.21^{bc}
Khartoum North	Groceries	12.30 ± 0.98^{ab}	4.33 ± 1.39^{cd}	3.44 ± 0.48^{cd}	0.80 ± 0.24^{bcd}
	Vendors	12.13 ± 0.74^{abc}	4.67 ± 0.90^{c}	3.42 ± 0.42^{cd}	0.80 ± 0.28^{bcd}
	Farms	11.97 ± 0.76^{bc}	5.15 ± 1.00^{b}	3.29 ± 0.43^{d}	0.71 ± 0.19^{d}
Omdurman	Groceries	12.06 ± 0.88^{abc}	4.53 ± 1.00^{c}	3.84 ± 0.45^{a}	0.79 ± 0.21^{bcd}
	Vendors	12.06 ± 0.85^{abc}	5.10 ± 0.94^{b}	3.88 ± 0.55^{a}	0.86 ± 0.23^{b}
Significant Level		**	**	**	**

Means in each row bearing the same superscript a, b, c letters are not significantly different (P > 0.05).
** = (P ≤ 0.01).

4. Discussion

The gross composition of cow's milk samples that were collected, including the morning or afternoon, was different in Khartoum State for the current study; for example, the mean total solids content of cow milk showed significant effects by source and season (Refer to Table 1). The total solids of collected milk samples showed higher values during the late summer season and a higher value from Omdurman city. Similarly, in India, the total solids of milk examined increased from 13.72% in December to 16.62% in June, then decreased gradually till November across Vechur and Kasargod dwarf cattle breeds [1]. They reported significant seasonal differences in the total solids content of Vechur cow's milk. The present finding contradicts those reported by Bernabucci *et al*. [23], where the lowest values occurred during the summer season and the highest during winter.

The cows' milk total solids mean was significantly affected by location (Refer to Table 2). Similarly, the total solids contents in cow milk (10.4 to 10.83%) were found to vary across studied sites in Ethiopia [9]. Although, total solids content was not significantly affected by sources, a higher value was still seen from the farms (Refer to Table 3).

The total solids content of cow's milk samples was significantly affected by the sources and seasons (Table 4, Table 5, Table 6), with higher value in milk samples of the winter season in Khartoum North. The total solids content of milk could be higher during autumn compared to spring and summer [24]. The geographical location of farms in Kosovo significantly influenced the total solids content of milk [25].

The fat content of cow milk samples showed complete effects by different seasons (Table 1). Warsama *et al.* [18] also found significant ($P \leq 0.001$) higher values for the fat content of cows' milk samples in Khartoum State, Sudan, during the winter season. Similarly, Nateghi *et al*. [26] found lower milk fat content during the summer season compared with those of the winter season. Kabil *et al.* [27] reported milk fat was higher during the winter season, while, it was lower during the summer and rainy seasons. Milk of the Vechur cow was slightly higher in fat content compared to that obtained from the Kasargod Dwarf cow, with a significant ($P < 0.05$) effect by season [1]. Not always will season influence milk fat, which could reach a lower level in summer [25]. Toledo *et al.* [28] reported milk fat percentage decreased notably during the summer (3.2%) compared with those during the spring (3.61%) and winter (3.80%). Changes could include feeding, breeding, and cattle management practices, including milking frequency and lack of heat stress during cold seasons [28]. Also, it could be the contribution of the combined effect of factors such as the lactation stage, individuality, health, and age of the animal [1]. The fat content of cow milk differed significantly by location (Table 2); the fat content was significantly higher in those collected from Omdurman city, which seemingly agreed with the findings of Elsheikh *et al.* [29]. Moreover, Mohammed and El Zubeir [30] reported fat content of milk samples was significantly ($P \leq 0.05$) higher in milk samples of south Omdurman compared to those from Northern Omdurman. The geographical location of farms could influence the milk fat [25]. Besides, the variations in breeds of cows, feeding strategy, and production systems [31]. This is particularly true because most of the herds in Omdurman are local cow breeds [32], which are known to produce higher milk fat [31, 33, 34]. Fat content could play a majo role in defining milk's energetic value and nutritional properties [9]. Fat needs to help in the pricing of milk, besides flavor, mouthfeel, and textural characteristics of milk and milk products [1]. The fat content of milk samples was significantly ($P < 0.01$) affected by the milk source (Refer to Table 3). Warsama *et al.* [18] found highly significant differences in the fat content of cow milk from different sources in Khartoum State. Soomro *et al.* [35] also reported that the fat content of milk obtained from producers was higher ($P < 0.05$) in fat content compared to those produced from vendors. The milk fat content could differ by location during the late summer and winter seasons (Refer to Table 4), as shown by the higher values of milk fat from Omdurman city during the winter. However, Mohamed and El Zubeir [36] found no significant difference between the milk samples collected from the different cities in Khartoum State during the summer and winter seasons. Variations of feed could be the reason, as Vanbergue *et al.* [37]

concluded that feeding treatments strongly influenced milk yield, milk fat, and protein yields in dairy cows.

The protein content of cow milk samples collected from Khartoum State differed frequently comparing late summer and winter seasons (Table 1), but not by sources comparing different seasons [18]. Similar reports have stated the protein content of milk was different during winter than in other seasons [15]. Different protein levels during the spring were reported [25]. Low milk components (total solids, solids-not-fat, fat, and proteins) values have been seen in the summer months [23], suggestive of α-CN concentration lower during autumn, while higher during summer than in winter. Feeding concentrates such as protein feed during variable seasons could play an important role [38]. Moreover, the protein content of cow milk samples differed by locations and sources during different seasons ($P < 0.05$) (Refer to Table 2, Table 3, Table 4). The milk protein values found by Warsama *et al.* [18] in Khartoum State (3.5 ± 0.9%) and that obtained for Baggara cattle (3.62 ± 0.31%) in South Kordofan State [33] supported the present study. However, the obtained values match those in Gadarif, Eastern Sudan [34], and Ethiopia [9]. The average protein content in the milk samples collected from Khartoum North was higher than those collected from Khartoum and Omdurman cities [36]. The geographical location of farms could significantly influence the protein content of milk but not its amino acid contents [25]. The location and consumer source of the sample could dramatically differ when comparing proteins [39].

The ash content of the milk samples collected during the late summer and winter seasons result (Refer to Table 1). However, the results do not agree with the study, showing differences between winter, spring, summer, and autumn in Greece, possibly due to breed and feed [15]. The ash content of milk for Vechur and Kasargod Dwarf cows in India differed significantly during the year's seasons [1]. Non-significant differences in the Murrah buffalo's milk due to geographical variations and the environment are the main factors contributing to the difference between the reported results [40]. In the current study, the ash content of the milk samples differed notably by source and location (Refer to Table 2, Table 3). Melese *et al*. [9] reported a higher value for the ash content in cow milk (0.93-0.95%) in Ethiopia. Whereas, Ayub *et al.* [41] reported that the ash content of milk samples was significantly affected by the location.

The higher total solids mean were in milk samples collected from farms during the late summer season and that collected from farms and vendors in Khartoum North (Refer to Table 4, Table 5, Table 6). Oppositively, Lakew *et al*. [42] reported higher total solids content in milk samples collected during the winter compared to the summer season in central the highlands of Ethiopia. Variations of total solids values could depend on many factors like geographical location, climate conditions, breed, and types of feed [23]. Meanwhile, the fat content could be influenced by milk sources during the late summer and winter seasons and locations (Table 5, Table 6). It was higher in milk samples collected from farms during the late summer season. Ahmed and El Zubeir [43] reported higher values for milk samples collected from farms in Khartoum State during the winter (4.54 ± 0.59%) and summer (4.50 ± 0.47%) seasons. Warsama *et al.* [18] reported that the the variactions in the fat content of milk were found in Sudan. This might be because the concentration sensitivity influenced dietary changes [37]. Nevertheless, the difference in milk fat could be due to the locations, feeding, and production systems of the cows [31]. Similarly, the protein content of milk samples differed by sources within season and location (Refer to Table 5, Table 6). However, Abdalmahmoud *et al*. [34] found non-significant ($P > 0.05$) differences in the protein content of cow milk samples across three sources in Gadarif town in Eastern Sudan. Ozdemir and Kahyaoglu [44] reported that protein content collected from different locations of Kastamonu Province in Turkey during summer and winter showed a significant difference. Protein remains a component of milk with nutritional value and technological suitability [9]. Also, in the current study, the ash content of milk appeared significantly affected by location and sources during both late summer and winter seasons (Refer to Table 4, Table 5, Table 6). However, Maurya *et al.* [45] reported that the ash content of milk did not vary between the breed, animal and season.

5. Conclusions

The present study reflects the quality of the gross composition of cow milk (fat, protein and total solids) within the reported standard values. This may also reflect the importance of cow milk in providing a nutritious food for human consumption in Khartoum State. However, the overall gross composition of raw cows' milk in Khartoum State by different sources during late summer and winter seasons could differ significantly, especially during the summer season. This situation should necessitate the introduction of collection centers alongside cooling facilities. Policy needs to be considered to help sustain gross milk compositional quality.

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Author Contributions

Tayseer Idrees contributed to the study's design, the samples, collected the samples, performed data analysis, interpreted the results and drafted the manuscript. Ibtisam El Zubeir supervised the candidate during the entire research period, approved the design and the obtained results and finalized the manuscript. Both authors reviewed and approved the final version of this manuscript.

Competing Interests

The authors have declared that no competing interests for the present manuscript.

Data Availability Statement

The data used in the present study will be available upon the request from the first author.

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