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Chemical composition of *Gariss* produced from milk of camels with different watering intervals using some traditional containers in Al-Koma Locality, North Darfur State, Sudan

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Abstract

Background The nomadic camels herders utilizing the extensive production system in Sudan depend mainly on fermented milk, locally known as *Gariss*, as their main stable food for several months during the year.

Methods This study was conducted to assess some factors (locations, types of containers used for preparing *Gariss* and camels watering intervals) affecting the compositional content of *Gariss* that is commonly prepared by nomadic camel herders. *Gariss* samples (n-118) were collected during February 2018, from nomadic herders in 4 locations in Al-Koma Locality, North Darfur State, Sudan.

Results and discussion The chemical analysis conducted during this study indicated that the mean levels of the total solids, fat, protein and ash content and the pH values of *Gariss* samples revealed 7.35 ± 0.22%, 2.58 ± 0.08%, 1.86 ± 0.04% and 0.67 ± 0.01% and 3.77 ± 0.03, respectively. The data showed that *Gariss* prepared in *Siin* showed the highest total solids (7.7 ± 0.71%), protein (2.02 ± 0.18%), fat (2.60 ± 0.19%) and ash (0.68 ± 0.04%) content, while it revealed the lowest pH value (3.61 ± 0.11). *Gariss* prepared in plastic containers showed the lowest total solids (7.30 ± 0.23%) and protein (1.48 ± 0.28%). Moreover, *Gariss* from milk of camels that drink water every 14 days revealed high values for total solids (7.91 ± 0.29%), fat (2.80 ± 0.11%), protein (1.99 ± 0.05%) and pH (3.78 ± 0.04), while it showed the lowest ash (0.67 ± 0.02%) content compared to those made from milk of camels with drinking water frequency of 10 days.

Conclusion The study concluded that the compositional content of *Gariss* was affected by the frequency of water drinking by camels in addition to the containers used for its preparation; as the compositional content of *Gariss* from *Siin* showed the best values followed by that stored in *Bokhsa*. Thus, the study recommends that *Siin* and *Bokhsa* should be considered as valuable ethnic containers in keeping camel fermented milk with better compositional content.

Keywords Compositional content, Camel milk, *Gariss*, Nomadic herders, Traditional processing, Sudan

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Introduction

The one humped camel was domesticated about 3000 B.C. in southern Arabia mainly for its meat and milk [1]. There is strong believes that dromedary camels entered to Meroe from Egypt, following either the River Nile or through the desert. This based on a specimen of camel hair rope of an old Kingdom, which was found at Fayum in upper Egypt 2980-2475 BC [2]. Meroe was the southern capital of the Napata/Meroitic Kingdom in Sudan that spanned the period c. 800 BC–c. 350 AD. Meroe plaque showed the existing of camel during that time and the oldest evidence is a bronze figure of a camel with a saddle dated back to 25–15 BC [2, 3]. Meanwhile, it was stated that the camels were probably entered the Sudan through the following routes: Egyptian route, North West African route during the 4–6 century and more recently the red sea route [4].

The bulk of camel population in the Sudan is found mainly in the arid and semi-arid parts of the country north of latitude 13 N°; camel belt [5]. The camel belt extends from 12 N° to 16 N°. The camel pastoralists are always moving over large area in search of food and water for their camels [6]. Generally, the camel types found in Darfur move north and south, to avoid the clay soil and Tsetse fly found at the southern part of the country during the rainy season, while searching for water and food [7]. Also, camel is vital to daily life for those people living in the desert, as a source of food, means of transportation and as medicines for diverse ailments since ancient times [8].

Camel milk is often the only regular food source for camel's owners and nomadic people [6]. The pastoralists rely on this milk throughout the year as it may contribute up to 50% of their nutrient [9]. Moreover, the camel milk besides being one of the main components of the pastoral community's basic staple diet in some areas of Africa and Asia [10, 11], it has significant health promoting values [10, 12, 13]. Hence it is common in these regions to recommend consumption of camel milk; either in a fresh or sour state [11, 14–16] in order to control diabetes and its complications [17]. Consumption of camel milk and its products are associated with antidiabetic, anti-cancerous, anti-hypertensive and many other health benefiting properties [18]. This because when camel milk composition is comparable to that of cow milk, it has predominant medium-chain fatty acids in fat, low lactose, and abundant vitamin C and iron [18].

Similar to most pastoral societies, camel milk is traditionally consumed in fermented forms in Sudan [14, 15, 19–22]. Because in Sudan, the camel's milk being abundant in remote localities; the camel herders living in the arid and semi-arid regions have to prepare *Gariss*; upon which they sustain their live for several months as a sole source of various nutrients [14, 15, 19, 20]. *Gariss* is a sour special full cream fermented camel milk in Sudan and the word *Gariss* locally means ̔pinching ̛ or stinging, denoting a high degree of sourness, although this is not necessarily true all the time [14, 15]. *Suusac* in Somali and Kenya [23], and *Shubat* in Asia [24] are the examples of similar products.

Gariss can be continuously produced for months in a large skin bag or *Siin* that contains previously soured product called starter to which fresh milk is added whenever part of the fermented product has been consumed [14, 15, 19, 20]. *Siin* usually is made after removing hair from goat skin and tanned using several local materials for its softening. In rural areas it is used as a manual churner for separating butter and butter milk. In the absence of a starter from a previous lot; particularly when using a new *Siin*; fermentation is initiated by adding a few seeds of black cumin and one onion bulb to produce the first batch of *Gariss*, then fresh camel milk is added to the *Siin* and usually, two large skin bags are used for the production of fermentation milk by tiding and hanging them on the saddle of special camel; called the camel *Gariss* [14, 15, 19]. Fermentation of milk into *Gariss* takes place while the camels are moving and due to the inherent jerk in the camel's walk; the milk in the bags is gently shaken during fermentation, which is attributed to lactic acid bacteria and alcohol-producing yeasts [14, 22].

In the Sudan, the ethnicity of camels and fermented camel milk is evidence in the ownership of camel and its husbandry management as well as utilization of its products. The nomadic tribes, especially those practiced complete nomadis, are usually move together including all family members following certain known routes, where the camels enjoy natural free pasture [21]. Commonly, the Sudanese camels are classified based on their conformational and tribal ownership [7]. Moreover, the socio-economic characteristics of nomadic camel herders revealed more or less similar pattern, while the special cultures and tradition of each tribe are conserved and honored for the sustainable livelihood [21].

Most of nomadic camel herder's families live in small tents made of different local materials including wool, wood and plastic materials and that every tent contains one leather bag for water and another one for preparation of *Gariss* [21, 25]. Women camel herders in nomadic production system are usually processed camel milk into *Gariss* for their households mostly using *Siin* and *Bokhsa*; wooden Gourd [20]. However, in the field it is prepared by shepherds when driving the camel for pastures in faraway places using 2 leather bags of tanned goat skin that carried on the back of the camel [19].

Fermented camel products generally have a longer shelf life than the original milk from which they are made [19, 26, 27]. *Gariss* is of great significant values due to its nutritional content, social impact and as a source of income [6]. Nomadic herders in most areas of Sudan don't usually sell camel milk and they are against the concept of selling milk as they believed that it is a gift from the God that should never been sold [21]. Never the less, some of the eldery women from the Shanabla tribe when they are around El Obied city; during dry seasons; they sell fermented camel milk in the local markets in order to satisfy the basic needs of their households [25]. However, most of produced milk is used to satisfy household and herders needs, or sometimes it is offered for free to people who need it for medicinal purposes [28]. When used to cure leishmaniasis or *kalazar;* an adult man who contacts the protozoal disease of the belly as well as other illness is sent out with the camel boys in remote pasture lands to live on *Gariss* alone as food for weeks or months unless he is fully cured [14]. However, when a woman or a child or an elderly person catches the infection, *Gariss* (or camel milk rob) of a special kind is made for the patient; at home; by mixing milk with 12 kinds of spices, then the mixture is fermented for 3 days in a pot that buried in the ground and the person to be treated is fed on this product; alone; for 12 days as cure [15]. Although *Gariss* is the main stable food produced by the nomads, no study was performed to evaluate its compositional content in North Darfur State that considered as one of the important state for rearing camels in Sudan. Thus, this study was designed to fill in this gap by evaluating some of the factors contributing to variation in the chemical composition of *Gariss* produced by nomadic camel herders located in Al-koma Locality, North Darfur State.

Materials and methods

The study area and *Gariss* samples collection

The area of study is Al-Koma Locality, North Darfur State, Sudan during February 2018. *Gariss* that was already prepared by nomadic camels' herders as their basic food was investigated. The samples ($n=118$) were obtained from four locations (Fig. 1); Sari ($n=30$), Om Hageleeg ($n=30$), Om Alhussain ($n=30$) and Al-Koma ($n=28$). The camels are browsing on the grass land and trees without any supplementary feeding, except in Al-Koma town, where the camels that kept inside the city are provided with extra feed or leftovers. The watering intervals for camels (Fig. 2) vary between 10 to 14 days. *Gariss* samples were collected into 50 ml clean sterilized containers from the original containers in which the samples were prepared by the camel herders. The containers used include *Siin*; traditional tanned goat skin; *Bokhsa*; Gourd, stainless steel and plastic containers (Figs. 3, 4). All the samples were packed into an ice container and transported to the laboratory of Dairy Chemistry at the Department of Dairy Production, Faculty of Animal Production, University of Khartoum for conducting the analysis.

Chemical analysis of *Gariss*

The total solids content of *Gariss* samples were determined according to the modified method of AOAC [29]. Five ml of *Gariss* samples were pre-heated on a steam bath for 10–15 min and then dried in an air oven for 3 h at 100 °C, after which they were transferred into a desiccator to cool and then weighted. Heating, cooling and weighting were repeated several times until the differences between the two successive weighting was less than 0.5 mg. The total solids content was calculated as follow:

$$\text{Total solids } (\%) = W1/W2 \times 100$$

where $W1$: weight of sample after drying, $W2$: weight of the original sample.

The fat content was performed by the Gerber method [30]. Ten milliners of sulfuric acid (density 1.815 g/ml at 20 °C) were poured into a clean dry Gerber tube, followed by the addition of 10.94 ml of *Gariss* sample. Then one ml of amyl alcohol (density 0.814–0.816 g/ml at 20 °C) and distilled water (at 20 °C) were added. The content was then thoroughly mixed till no white particles could be seen. The Gerber tubes were centrifuged at 1100 revolution per minute (rpm) for 3 min and the tubes were then transferred into a water bath at 65 °C for 3 min. The fat percent was then read out directly from the fat column.

The protein content was determined by Kjeldahl method [29]. In clean dry Kjeldahl flask, 10 ml of *Gariss* sample were placed followed by the addition of catalyst powder (Na_2So_4 and the equivalent of 0.1 mg Hg). Twenty five milliners of concentrated sulfuric acid (density 1.86 g/ml at 20 °C) were added to the flask and the mixture was then digested on a digestion heater until a clear solution was obtained (3 h). The flasks were then removed and left to cool. The digested samples were poured into volumetric flasks (100 ml) and diluted to 100 ml with distilled water. Five milliners were taken and neutralized using 10 ml 40% NaOH. The distillate was received into a conical flask containing 25 ml of 2% boric acid and 3 drops of 0.1 indicators (bromocresol green and methyl red). The distillation was continued until the volume in the flask was 75 ml. The flask was then removed from the desiccator and was titrated against HCl (0.1N) until the end point was obtained (red color). The protein content was calculated as follows:

$$\text{Nitrogen } (\%) = T \times 0.1 \times 20 \times 0.014/\text{weight of sample} \times 100$$
$$\text{Protein}(\%) = \text{Nitrogen } (\%) \times 6.38$$

Fig. 1 Sudan is located in the north eastern region of Africa, the greenish area showed the camel belt, however camels are also found outside this zone. The study areas in Al-Koma Locality in North Darfur State from which camel *Gariss* samples were collected are shown with black dots

where T: Titration figure, 0.1: Normality of HCl, 0.014: Atomic weight of nitrogen, 20: Dilation factor.

The ash content was determined using oven draft method [29]. Five ml of *Gariss* sample were weighted into a suitable clean dry crucible and evaporated to dryness on a steam bath. The crucibles were placed in a muffle furnace at 550 °C for 1.5–2 h. It was cooled in a desiccator and weighted. The ash content was then calculated as follow:

$$\text{Ash } (\%) = W1/W2 \times 100$$

where $W1$ = weight of ash, $W2$ = weight of sample.

The pH of *Gariss* samples was determined directly using pH meter Microprocessor mark (HANNA pH 210, India) according to Bradley [30].

Statistical analysis

The collected data were subjected to analysis of variance using one way ANOVA for the compositional content of *Gariss* samples using SPSS (Statistical Package for Social Sciences) version 11.5. The mean separation was done using Duncan Multiple Range Test [31]. The significant differences was considered at ($P < 0.05$).

Results

Compositional content of *Gariss* obtained from camel herders in Al-Koma Locality

Total solids content

The obtained overall mean of the total solids content revealed 7.35 ± 0.22% for *Gariss* samples produced by

Fig. 2 Camels' herders waiting for watering their camels and to collect the water for their domestic use in Al-Koma Locality in North Darfur State, usually this practice is done at regular intervals; 7–14; while it might extend up to a month where green vegetations are available

Fig. 3 Samples from large plastic containers used for preparing *Gariss* for daily consumption by herdsmen in Al-Koma Locality, while large *Siin* is shown at the back of camel as a main storing container for the long duration, this camel *Gariss* is usually used to ferment camel milk by its continuous jerk

the camel herders in the 4 locations of Al-Koma Locality. The samples from Sari area showed the highest total solids (8.35 ± 0.28%) and those from Om-Alhussain area showed the lowest content (6.70 ± 0.35%) as shown in Table 1. Moreover, the total solids content of *Gariss* samples recorded significant ($P < 0.05$) variations between the area from which the samples were collected (Table 1).

Fig. 4 *Gariss* prepared and stored using *Siin* and *Bokhsa*, A household in Gadarif State at eastern part of Sudan, a nomadic women camel herder is removing part of the already prepared *Gariss* from *Siin*. *Bokhsa*; is hanging on the upper part of a wooden corner of the tent; nomadic house

Fat content

Significant differences ($P < 0.05$) for the fat content were found between *Gariss* samples prepared by the camel herders in the 4 locations of Al-Koma Locality (Table 1). The fat content was high in *Gariss* samples obtained from Om-Hageleeg area (2.91 ± 0.21%) followed by those collected from Sari (2.71 ± 0.09%) compared to the samples obtained from Al-Koma (2.5 ± 0.14%) and Om Alhussain (2.25 ± 0.16%). The average mean revealed 2.58 ± 0.08% (Table 1).

Protein content

The overall mean for protein content of *Gariss* samples obtained from the camel herders was 1.86 ± 0.04%. The samples from Om-Hageleeg area showed significantly ($P < 0.05$) higher protein content (2.08 ± 0.01%) compared to the samples of *Gariss* collected from Sari (1.91 ± 0.05%), Al-Koma (1.71 ± 0.07%) and Om-Alhussain (1.70%) as shown in Table 1.

Ash content

The mean of ash content for all *Gariss* samples collected from camel herders in Al-Koma Locality revealed 0.67 ± 0.01% (Table 1). The *Gariss* samples obtained from Al-Koma area showed the highest ash content (0.69 ± 0.02%), while samples that collected from Om-Hageleeg area showed the lowest mean (0.65 ± 0.04%). However, non-significant ($P > 0.05$) difference was found for ash content of *Gariss* from different chosen areas of Al-Koma Locality.

Table 1 Chemical composition of fermented camel milk "*Gariss*" obtained from four different locations in Al-koma Locality, North Darfur State

Constituents	Areas				Total	Sig. level
	Sari	Om-Hageleeg	Om-Alhussain	Al-Koma		
Total solids (%)	8.35 ± 0.28^{a}	7.28 ± 0.58^{ab}	6.70 ± 0.35^{b}	6.87 ± 0.50^{bc}	7.35 ± 0.22	0.025*
Fat (%)	2.71 ± 0.09^{a}	2.91 ± 0.21^{a}	2.25 ± 0.16^{b}	2.50 ± 0.14^{ab}	2.58 ± 0.08	0.025*
Protein (%)	$1.91 \pm .05^{ab}$	2.08 ± 0.10^{a}	$1.70 \pm .07^{b}$	$1.71 \pm .07^{b}$	1.86 ± 0.04	0.002**
Ash (%)	0.68 ± 0.02^{a}	0.65 ± 0.04^{a}	0.66 ± 0.03^{a}	0.69 ± 0.02^{a}	0.67 ± 0.01	0.872^{NS}
pH	3.77 ± 0.05^{a}	3.78 ± 0.06^{a}	3.66 ± 0.06^{a}	3.88 ± 0.08^{a}	3.77 ± 0.03	0.226^{NS}

NS no significant

^{a,b,c} Mean values within the same row with different superscript letter are significantly different at $P < 0.05$

*Significant at $P < 0.5$

**Significant at $P < 0.01$

pH

The average value for the pH of *Gariss* samples collected from the camel herders in the 4 locations in Al-Koma Locality was 3.77 ± 0.03. The samples from Al-Koma area revealed the highest pH value (3.88 ± 0.08), while *Gariss* samples that collected from Om-Alhussain area showed the lowest one (3.66 ± 0.6). Non significant ($P > 0.05$) difference was obtained for pH of *Gariss* samples collected from the 4 investigated areas of Al-Koma Locality (Table 1).

Compositional content of *Gariss* samples prepared in different containers by camel herders in Al-koma Locality

The present result showed non-significant ($P > 0.05$) variations for the compositional content of *Gariss* prepared and kept into different containers (Table 2). The total solids content was high in *Gariss* samples collected from *Siin* ($7.70 \pm 0.71\%$) compared to that obtained from stainless steel ($7.50 \pm 0.00\%$), *Bokhsa* ($7.35 \pm 2.95\%$) and plastic containers ($7.30 \pm 0.23\%$) as shown in Table 2. Also, the fat content of *Gariss* was high in samples obtained from *Siin* ($2.60 \pm 0.19\%$), while the fat content of *Gariss* prepared using plastic containers, stainless steel and *Bokhsa* revealed $2.58 \pm 0.08\%$, $2.4 \pm 0.00\%$ and $2.40 \pm 1.3\%$, respectively (Table 2). Moreover, the result in Table 2 showed that the highest protein value was found in *Gariss* samples prepared in *Siin* ($2.02 \pm 0.18\%$) compared to the protein content of *Gariss* prepared using plastic containers ($1.85 \pm 0.04\%$), stainless steel ($1.69 \pm 0.09\%$) and *Bokhsa* (1.48%). However, the ash content of *Gariss* samples collected from *Bokhsa* showed the highest value ($0.68 \pm 0.04\%$) followed by those prepared using *Siin* ($0.67 \pm 0.15\%$) and stainless steel containers ($0.67 \pm 0.00\%$) compared to that made using plastic containers ($0.55 \pm 0.03\%$) as shown in Table 2. Meanwhile, the highest pH of *Gariss* was found in the samples prepared using stainless steel containers (3.95 ± 0.65) compared to that prepared in *Bokhsa* (3.80 ± 0.10), plastic containers (3.78 ± 0.03) and *Siin* (3.61 ± 0.11) as shown in Table 2.

Table 2 Chemical composition of *Gariss* samples as affected by the types of containers used by camel herders in Al-koma Locality, North Darfur State

Types of containers	Chemical composition				
	Total solids (%)	Fat (%)	Protein (%)	Ash (%)	pH
Siin	7.70 ± 0.71	2.60 ± 0.19	2.02 ± 0.18	0.67 ± 0.15	3.61 ± 0.11
Bokhsa	7.35 ± 2.95	2.40 ± 1.30	1.48 ± 0.28	0.68 ± 0.04	3.80 ± 0.10
Plastic	7.30 ± 0.23	2.58 ± 0.08	1.85 ± 0.04	0.55 ± 0.03	3.78 ± 0.03
Stainless steel	7.50 ± 0.00	2.40 ± 0.00	1.69 ± 0.09	0.67 ± 0.00	3.95 ± 0.65
Significant level	0.336^{NS}	0.986^{NS}	0.467^{NS}	0.656^{NS}	0.956^{NS}
Total	7.35 ± 0.22	2.58 ± 0.08	1.86 ± 0.04	0.67 ± 0.01	3.77 ± 0.03

NS no significant

Table 3 Effect of watering interval of camels on chemical composition of *Gariss* in Al-Koma Locality, North Darfur State

Watering interval of camel	Chemical composition of *Gariss*				
	TS (%)	Fat (%)	Protein (%)	Ash (%)	pH
10 days	6.79 ± 0.03	2.37 ± 0.10	1.71 ± 0.05	0.68 ± 0.02	3.77 ± 0.05
14 days	7.91 ± 0.29	2.80 ± 0.11	1.99 ± 0.05	0.67 ± 0.02	3.78 ± 0.04
Significant level	0.011*	0.007**	0.001***	0.788^{NS}	0.906^{NS}

TS total solids

^{NS} Not significant

*Significant at $P < 0.05$

**Significant at $P < 0.01$

***Significant at $P < 0.001$

Effect of watering interval of camels on the compositional content of *Gariss* processed by camel herders in Al-Koma Locality

The data in Table 3 showed the effect of the watering interval of camels on the compositional content of *Gariss*. There were significantly higher values for protein ($P < 0.001$), fat ($P < 0.01$) and total solids ($P < 0.05$) contents of *Gariss*. The total solids content of *Gariss* prepared using milk from camels that drink water every 14 days was 7.91 ± 0.29%, while it was 6.79 ± 0.03% in *Gariss* using milk from camels that drink water every 10 days (Table 3). The study showed that the value of fat content of *Gariss* prepared using milk from camels that drink water every 14 days was 2.80 ± 0.11%, while it was 2.37 ± 0.10% for the *Gariss* prepared using milk from camels with drinking water intervals of 10 days. The percentage of protein in milk of camels drinking every 10 days was less than the camels drinking water every 14 days. The protein content of *Gariss* prepared from milk of camels with drinking frequency of water every 14 days was high (1.99 ± 0.05%) compared to those of *Gariss* prepared using camels milk with frequency of drinking water every 10 days (1.71 ± 0.05%) as shown in Table 3. However the ash content of *Gariss* prepared using milk from camels that drink water at intervals of 10 days revealed 0.68 ± 0.02% compared to the *Gariss* samples prepared from milk of camels that drink water every 14 days (0.67 ± 0.02%). The pH of *Gariss* prepared from milk of camels that drink water every 10 days was 3.77 ± 0.05, while in the *Gariss* prepared using milk of camels that drink water every 14 days was 3.78 (Table 3). The present data showed non-significant ($P > 0.05$) differences in both ash and pH values as affected by watering intervals of camels (Table 3).

Discussion

The result obtained from the analysis of the compositional content of the collected *Gariss* samples produced from the different areas of Al-Koma Locality revealed variations (Table 1). The compositional content of *Gariss* was affected by the management system of she camels as well as the preparation conditions [19]. Also, variations in the chemical composition due to the differences in the temperature and storage period of *Gariss* were reported [26]. Moreover, the chemical composition of *Gariss* samples collected during dry and rainy seasons from nomadic camel herders in Gadarif State, eastern Sudan showed significant differences [20].

The obtained values for the total solids content of *Gariss* samples were lower than those reported for the traditional Kenyan fermented camel milk; *Suusac* [32] and Sudanese camel milk *Gariss* samples examined previously [19, 20]. However, the present obtained values were in the range of total solids content reported for the *Gariss* samples made in the laboratory [26] and those collected from transhumance camel herders in Sudan [19]. The lower total solids content obtained could be due to the high water content in camel milk [33]. Moreover, the availability of quality feed including the green fodder and the continuous water supply strongly influenced the total solids content of camel milk [33, 34] and consequently its fermented products that showed watery texture [27].

The fat content of *Gariss* samples from different locations of Al-Koma Locality were in a range of 2.25% and 2.91%, which supported the fat content (2.55%) reported in *Gariss* samples collected from Butana area of Sudan [26]. The result was also similar to the fat content of *Dhanaan*, which is Ethiopian fermented camel milk [35]. However, the fat content for the *Gariss* samples collected from transhumance camel herders was slightly higher [19]. Also, high fat content was reported for the *Gariss* samples collected during the dry and rainy seasons (3.73% ± 0.11 vs. 3.06% ± 0.22, respectively) from nomadic women herders in Al Gadarif State, Sudan [20]. Moreover, the fat content of *Suusac* in Kenya revealed 4% [32]. The differences might be due to the variations of the fat content in the milk used for production of the *Gariss* [19]. The lower values of camel milk fat that often associated with the traditional nomadic system might be due to lack of nutrient supplements [34]. However, *Garris*; is pleasantly sour product with a characteristic buttery flavor that is used as a common food in the rural areas of Middle and Western Sudan where it is drunk on its own or consumed with other food products by camels owners [22].

The protein content (1.70–2.08%) in the collected *Gariss* samples from different areas of Al-Koma Locality was in the range of protein content (2.32%) of fermented camel milk obtained in the laboratory [26]. Also, higher value for protein content of *Gariss* produced by nomadic herders was reported previously [19]. Moreover, it was lower than protein content (3.06%) of *Gariss* collected during the rainy and dry seasons [20]. Previously, it was reported that the availability of high feed quality explains the variations in milk protein content between camels kept in the different locations and production systems [33, 34]. The milk protein is very important especially for nomadic camel herders because it is the only source of protein for providing sufficient amount of amino acids in their relatively poor environment [36].

The ash content of *Gariss* collected samples from the four different choosen areas of Al-Koma Locality were found to range between 0.65 and 0.69%, which were lower than the average ash content of the fermented camel milk reported previously [26]. However higher ash content of *Gariss* was also reported [19]. Meanwhile, lower ash content of *Gariss* collected from Al Gadarif State was found during rainy and dry seasons [20]. The variations reported could be due to the differences in the locations, production systems [19] and the processing method [20].

The result showed that pH value (3.66–3.88) of *Gariss* samples collected from Al-Koma Locality were in the range of pH reported in *Gariss* examined previously [19, 26]. Meanwhile, values of 4.42; 1.72% and 1.40% for the pH, titratable acidity and ethanol content of *Gariss*, respectively, were reported in a previous study [22]. Also, similar pH value was reported for *Gariss* samples collected from Al Gadarif State during the dry season [20]. However, the pH was 4.52 ± 0.20 during the rainy season, which could be due to the continuous addition of fresh milk that was available during autumn season; as the camels are rearing very near to their owners [20]. Generally the fermentation of milk via the action of microorganisms result in lowering the pH values [27]. The low obtained pH values could be due to the type of camel milk, as; locally; *Gariss* means sour and it is kept to be fermented continuously by adding some fresh milk [19]. Fermented camel milk in Sudan is also known as hameedh or humadah, which also means sour [20]. These differences in pH ranges can also be explained by the duration of storage and the degree of fermentation temperature [27].

Generally the variations found in the compositional content of *Gariss* (Table 1) might also be due to the differences in the preparation methods of camel's milk products [15, 20, 27, 35] and their storage conditions [20, 26, 27, 37]. The obtained differences could also be due to variations of geographical locations, milk composition and seasons [20, 33] and feeding conditions of the milking camels [33] as well as the method of *Gariss* processing and preservation [20].

Table 2 shows variations in the total solids, fat and protein content between *Gariss* prepared in *Siin* and other containers. The variations in the chemical composition of *Gariss* samples might be due to the types of used containers. A previous data revealed that 42.1% of nomadic women camel herders are using either *Siin* or plastic containers; however the use of *Bokhsa* and stainless steel containers for preparing *Gariss* revealed 10.5% and 5.3% in Al Gadarif State [20]. *Bokhsa* and *Siin* were only used by women in Al-Koma Locality. The slight variations observed in the chemical composition (Table 2) could be attributed to the similar processing conditions practiced. The higher values obtained for *Gariss* prepared using *Siin* matches with the lower pH, which is due to the rate of fermentation (Table 2), which is high when using *Bokhsa* due to the lack of adding fresh milk. *Siin* followed by *Bokhsa* and the plastic containers keep the products original temperature compared to stainless steel containers that absorbed the heat more compared to the other used containers. Furthermore, the temperature is the most important factor in controlling the growth of the fermentative microorganisms in the milk and dairy products [37]. When the values of total solids are high, this might be because the herders usually remove the upper watery part; resulted from wheying off; of *Gariss* in order to substitute their need for drinking water, which is lacking in such environment. Similar observation was reported during the dry seasons [20]. The seasonal systemic movement of camel herders is because of climate conditions coupled with the lack of water [28]. This lack of water affected both humans and the animals.

The data concerning the pH (Table 2) showed that the lowest value was in *Gariss* prepared using *Siin* (3.61). The obtained value was lower than that reported (4.42) for the pH of *Gariss* examined previously [20]. This low pH could be due to the variations of camel milk, type of containers used and the temperature, which showed direct effect on the pH values. The low pH values of *Gariss* indicate major contribution of lactic acid bacteria and yeast in the fermentation [15]. Similarly, significantly ($P < 0.05$) low pH was found when comparing *Gariss* that was prepared using stainless steel (3.95 ± 0.45), plastic containers (3.59 ± 0.16), *Siin* (3.87 ± 0.16) and *Bokhsa* (4.55 ± 0.31) [20]. These findings suggested that *Bokhsa* is a good container to be used by the nomadic herders where there is no alternative for proper storing of fermented products.

The present study (Table 3) showed significant variations in the compositional content of *Gariss* as was affected by the watering interval of she camels whose milk was used for preparing *Gariss*. This result is in agreement with those reported earlier [19, 35]. Camel milk yield and composition were significantly affected by husbandry practices including watering intervals [38]. Camel milk is regularly processed into *Gariss*, as it was noticed that drinking fresh unprocessed camel milk is very rare among nomads because they believe that *Gariss* is much healthier [21, 25].

The variations in the chemical composition of camel milk might be attributed to many factors based on the physiological and environmental conditions such as the species of camel, age and heath condition, difference in genotype, seasonal conditions and parity of camel [39]. Moreover, other factors include ecological localities for camels, water availability and green fodders [34, 38], in addition to stage of lactation and fermentation period [40, 41]. Furthermore, fresh camel milk and their products have unique flavor and good nutritional values, therefore they can compete in the market if made available on supermarket shelves and packed into an attractive packaging [12]. It is also important that final products should have acceptable sensory attributes such as taste, aroma, color and texture during their shelf life.

Conclusion

Gariss consumed in Al-Koma Locality has good compositional content, moreover, the chemical composition was found to be affected by the watering intervals of the camels, locations and the containers used. The best recommended containers according to the present study are the ethnic *Siin* and *Bokhsa* to prepare and store fermented camel milk. This study recommends the benefiting from camel milk and fermented products; produced in the desert and semi-desert areas; to the urban consumers to take the advantage of the value of camel milk as organic and functional food.

Abbreviations

AOAC Association of Official Analytical Chemists
ANOVA Analysis of variance

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Author contributions

HIIO contributed 50% of the work, IEME contributed 35% of the work and ESS contributed 15% of the work. Moreover, all authors read and approved the final manuscript.

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Availability of data and materials

The data generated during the current study will be available upon request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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