Effect of Production Systems on Micro-Mineral Composition of Camel Milk Produced in Sudan

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Abstract: This study was performed to evaluate the impact of three different management systems, (traditional nomadic, semi-nomadic, and intensive) on the macro-mineral content of milk of camels in different lactation stages and parity orders. The samples (120) were examined to determine the calcium (Ca), magnesium (Mg), sodium (Na), phosphorus (P), and potassium (K) contents of camel milk collected from North Darfur and Khartoum states. The results indicated the highest Ca (154.6±2.3 mg/100g), Na (215.6±8.39 mg/100g), and P (77.2±1.43 mg/100g) content in the milk of camels kept in the semi-nomadic production system in the Green Valley (Khartoum State) and the lowest values (111.4±2.2 mg/100g, 148.6±5.12 mg/100g and 66.9±1.39 mg/100g, respectively) were reported for the camel milk collected from a nomadic system in North Darfour State. Both areas revealed the lowest Mg contents in camel milk, while Mg content of camel milk showed the highest content in the camels reared in the semi-nomadic system of Hamad well (39.1±2.01 mg/100g) and the intensive system in El Huda (34.0±2.01 mg/100g). However, significantly higher value for K (317.8±12.17 mg/100g) was recorded in the milk obtained from camel browse in the nomadic system of North Darfour State. Moreover, Ca, Mg and Na contents showed a reduction in the milk of camels with the advancement of parity, meanwhile, K and P revealed an increasing trend. However, there was no significant difference between the macro mineral contents of camel milk as influenced by the variations of parity orders and age of camels. In conclusion, results demonstrated high variability in the macro-mineral contents of camel milk, this variability was associated with the types of production systems, while slight variation might occur for the parity orders, lactation stages and the age of camels.

Keywords: Camel Milk, Production System, Nomadic, Semi Nomadic, Intensive, Parity Orders, Stage of Lactation, Age.

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1. Introduction

Sudan has the second highest camel population globally, reaching about 4.8 million heads (MOARF, 2016). Camels have critical role for humans, especially in the nomadic system including workforce, source of milk, meat, and wool, and source of transportation (Akhmetsadykova et al., 2022). In Sudan, traditional nomadic system is widely used for raring of camels (Dowelmadina et al., 2015; El Zubeir and Nour, 2006). This is in addition to the other three

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management systems including the semi-nomadic or transhumance, sedentary or semi-sedentary, and the intensive management systems (Dowelmadina et al., 2015). Pastoral systems are important for the large segments of population in the vast semi-arid and arid areas of Africa, receiving erratic and unpredictable rainfall (Tilahun et al., 2017). Moreover, pastoral system is based on livestock (including camels, cattle and small ruminants) rearing.

In Sudan, camel milk is consumed fresh or traditionally fermented form, however, selling is rarely practiced. Although consumers prefer camel milk over milk of cows and other ruminants, however, major reasons for limited marketing and consumption of camel milk are related to its inaccessibility and limited awareness regarding its nutritional and pharmaceutical benefits (Ait El Alia et al., 2023). Moreover, camel herders in the traditional systems of production rarely accept selling of camel milk (Musa et al., 2006; Shuiep and El Zubeir, 2012). Furthermore, lack of well-established camel dairy farms in the country is also a major limitation for its sales and marketing (Shuiep and El Zubeir, 2008). Its demand, in domestic as well as foreign markets, is rapidly increasing (Akhmetsadykova et al., 2022; Mohammadabadi et al., 2022). Recent commercialization efforts are linked to the initiation of new semi-intensive camel system, e.g., big towns of Sudan and Khartoum State (Babiker and El Zubeir, 2014; Dowelmadina et al., 2015; Shuiep and El Zubeir, 2012).

Generally, the composition of camel milk is much similar to the milk of cows and other ruminants (Al Haj and Al Kanhal, 2010; Abrhaley and Leta, 2018; Arain et al., 2022; Benmeziane– Derradji, 2021; Seifu, 2022). However, camel milk has several unique biological functionalities e.g., high levels of immune-boosting immunoglobulins and antimicrobial peptides, unsaturated fatty acids (Ayyash et al., 2021; El-Hanafy et al., 2023; Ho et al., 2022). It is a rich source of macro-nutrients and minerals; vitamins (vitamin B, C, K) (Ait El Alia et al., 2023; Jilo and Tegegne, 2016; Seifu, 2022; Zibaee et al., 2015).

Since ancient times camel milk is widely used for the treatment of digestive disorders, anemia, malnutrition and infections, and source of immune booster (Muthukumaran et al., 2022). Camel milk contains low concentrations of fats and lactose (Yoganandi et al., 2014). Due to low lactose content, people with lactose intolerance can easily digest it, without adverse effects (Hammam, 2019; Kaskous, 2016). Camel milk is more heat-resistant than cow's milk and does not quickly denature, making it useful for some industrial application

Camel milk has been shown to have antidiabetic effects (Swelum et al., 2021), due to its low glycemic index, high insulin content, and unique combination of fatty acids i.e., small amounts of short-chain fatty acids, but higher content of long-chain fatty acids (Malik et al., 2012; Sumaira, et al., 2020; Vincenzetti, et al., 2022). Camel milk has a white opaque color, faint sweetish odor and a unique taste and texture that is different from other types of milk (Vincenzetti, et al., 2022).

She-camels that browse in the nomadic systems of Sinnar State, Gezira State and Khartoum State (Sudan) produced mineral-rich milk, as compared to the other production systems (Elhassan et al., 2016). Furthermore, camel milk produced in traditional nomadic systems is considered to be superior with better gross chemical composition, as compared to the semi-intensive production system (Babiker and El Zubeir, 2014; Dowelmadina et al., 2014; Mohamed and El Zubeir, 2020; Shuiep et al., 2014).

North Darfour State is rated in the fourth position among the states of Sudan in the ownership of camel population, however, information about the camel milk content in that region is rarely available in the literature. Present study was performed to examine the influence of management systems, lactation stages, parity orders and camel age on the mineral contents of camel milk.

2. Materials and Methods

2.1. Study Sites

This study was performed from August to November 2018. Healthy camels (120) were selected, from four locations: Alkoma locality (North Darfur State), Green Valley in East Nile, Hamad well and El Huda in West Omdurman (Khartoum State) (Fig. 1), for collection of milk samples. In Alkoma locality, Northern Darfur (12° and 20° North, longitude 24° and 27.6° East). Rainy season is extended from May to October; however, rainfall is mainly centered from July to August. The rangeland extended from semi-desert (north) to savannah (south). Hence the rich natural resources make it suitable for grazing pasture, where camels are kept in a nomadic system.

Khartoum State (15° and 16.45° North, longitude 31° and 34.4° East) is located in the semi-desert ecological zone, where different forms of camel rearing are practiced for milk production (Fig. 1).

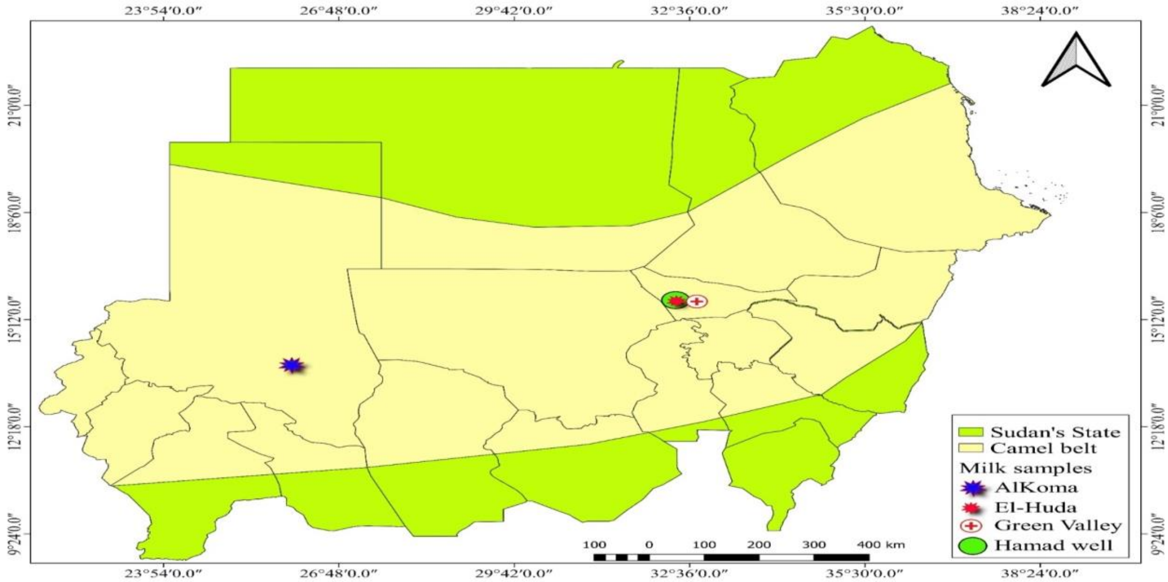

Fig. 1 A map showing different study sites used for camel milk collection

The study was designed to study the impact of different management systems on the macro-mineral contents of camel milk, collected from different locations. Moreover, the effect of parity orders, lactation stages and age of female camels were the factors regulating the mineral content of camel milk.

2.2. Description of Herds Management

Three different management systems, i.e., traditional nomadic system (North Darfur State), semi-nomadic and intensive s (Khartoum State) were included in this study. In the traditional nomadic system, camels spend most of their time browsing and grazing the natural plants in pasture. Contrarily, in the semi-nomadic system, they browse part of the day at pasture and were kept at night in pens. However, in the intensive system camels were kept in pens throughout the year. Moreover, the daily ration for camels in the intensive system consists of a mixture of sorghum and groundnut cake, and adequate water supply. Restricted water intake in nomadic and semi nomadic production systems is because of limited water sources. All camels in the three management systems were hand milked 2-3 times a day.

2.3. Sources and Collection of Milk Samples

Samples of camel milk (120) were collected from 3 different management systems across four distict geographical locations. The samples were classified according to the different factors examined in this study. The investigated she-camels were in different parity numbers, lactation stages and ages.

Raw camel milk samples were collected in Sterile bottles (500 ml) were used to collect samples of raw camel milk, subsequently labeled, stored in an ice box and shifted to the laboratory, located at Department of Dairy Production, Faculty of Animal Production, University of Khartoum, Sudan, for biochemical analysis.

2.4. Determination of Mineral Contents of Camel Milk

Milk minerals were determined for Ca, Na, Mg, K and P. After making the ash (AOAC, 2003), the residual extract was tested to determine Ca and Mg contents following protocol described by Chapman and Pratt (1961). Ash extract method, using Flame photometer (EEL 12700, England) was used for the determination of sodium and potassium contents. The phosphorus content of milk samples was determined using using spectrophotometer (UV mini 1240, Shimadzo, Japan) following Vanadate-molybdate yellow calorimetric method (Chapman and Pratt, 1961).

2.5. Statistical Analysis

Analysis of Variances (ANOVA) were calculated through general linear model (univariate). Duncan Multiple Range Test (DMRT) was utilized to separate treatment means. IPM SPSS (version 22; SPSS Inc., Chicago, USA (2013) was used for analysis.

3. Results

3.1. Effect of Production System on Macro-Mineral Contents of Camel Milk

Mineral contents in the samples of camel milk were significantly influenced by the management systems in which she-camels are reared. The camels browse in the nomadic system at North Darfur State recorded the lowest means of Ca (111.4±2.2 mg/100g), Na (148.6±5.12 mg/100g), Mg (23.8±1.20 mg/100g) and P (66.9±1.39 mg/100g) and the higher value of K (317.8±12.17 mg/100g). However, the milk of she-camels reared in semi-nomadic system at East Nile (Khartoum State) revealed the higher means of Ca (154.6±2.3 mg/100g), Na (215.6±8.39 mg/100g) and P (77.2±1.43 mg/100g). The higher value of Mg (39.1±2.01 mg/100g) was recorded for milk samples collected from camels reared in semi-nomadic system at Hamad well area (Khartoum State).

3.2. Effect of Parity Order on Macro-Minerals Content of Camel Milk

Table 2 showed that the parity orders of she-camels revealed non-significant (P>.05) variations on the levels of Ca, Na and Mg of camel milk samples collected from nomadic (North Darfur), intensive (El Huda) and semi-nomadic (East Nile) production systems, respectively. However, the levels of Ca, K and Na in the milk samples collected from camels in the nomadic system (North Darfur) were higher (115.1, 160.6 and 340.2 mg/100g, respectively) in camels, in their third and fourth parities as compared to those at either earlier or later parities. On the other hand, Mg and P content in milk collected from camels at the third and fourth parities recorded the lowest values (21.2 and 64.6 mg/100g, respectively). Furthermore, K content showed high values in all parity orders (Table 2).

The milk collected from camels reared in a semi-nomadic system (East Nile, Khartoum State) also showed that the number of parity did not significantly (P>0.05) influence Ca, K, Na, and P levels in the camel milk. The higher value of Ca (162.7 mg/100g) was recorded in the milk of she-camels with more than 4 parities, while the high Na (241.6 mg/100g) and Mg (26.8 mg/100g) were shown for milk of she-camels at their first and second parities. Meanwhile higher K (211.7 mg/100g) and P (78.3 mg/100g) were obtained in the milk of she-camels at their third and fourth parities (Table 2). Moreover, the data indicated that all studied minerals content of milk were not significantly (P>0.05) different among she-camels reared in the semi-nomadic production system of Hamad well due to variation of the parity number (Table 2). The values of Ca, Na and Mg showed a reduction in the milk from camels in their latter parities, meanwhile, the values of K and P revealed an increasing trend (Table 2).

The mineral contents of milk obtained from camels kept in an intensive production system at El Huda showed a similar trend to that of camels reared in the semi-nomadic system. There were no significant variations between the camel milk due to variations of parity number except Na content (Table 2).

3.3. Effect of Stage of Lactation on Macro-Minerals Content of Camel Milk

Mineral contents of camel milk obtained from the nomadic system (North Darfur) were not statistically influenced by the lactation stage (Table 3), except calcium. It recorded high significant variations between the mid (124.0±6.6 mg/100g) lactation compared to early (108.0±3.5 mg/100g) and late (108.4±2.5 mg/100g) lactation stages.

The lactation stages of camels reared in semi-nomadic system of East Nile (Khartoum State) revealed significantly different levels of Na, K and P content in the milk, meanwhile no variations were observed in Ca and Mg (Table 3). In semi-nomadic system at Hamad well area (Khartoum State), camels in the mid and late lactation stages showed significant variations in Ca and Mg contents of milk as shown in Table 3. However, Na and P contents of milk were affected significantly by the lactation stages of camels that kept in the intensive system at El Huda area (Khartoum State) as shown in Table 3.

3.4. Influence of Camel Age on the Macro-Minerals Content of Milk

The data presented in Table 4 showed that the age/years of camels that browse in the nomadic systems at North Darfur and the semi-nomadic of East Nile at Khartoum State secured non-significant (P>0.05) variations on the Ca, Na, Mg, K and P content of the milk samples.

Table 1. Effect of production system in different locations on macro-minerals content of camel milk

Production system	Location	Minerals content (mg/100g)				
		Ca	Na	Mg	K	P
Nomadic	**North Darfur**	111.4^{c}±2.2	148.6^{b}±5.12	23.8^{c}±1.20	317.8^{a}±12.17	66.9^{b}±1.39
Semi-nomadic	**Green Valley**	154.6^{a}±2.3	215.6^{a}±8.39	24.5^{c}±0.91	197.4^{c}±10.49	77.2^{a}±1.43
Semi-nomadic	**Hamad well**	116.8^{bc}±4.5	184.7^{a}±11.26	39.1^{a}±2.01	277.7^{b}±17.28	68.8^{b}±2.77
Intensive	**El Huda**	124.0^{b}±2.1	199.7^{a}±20.28	34.0^{b}±2.01	211.6^{c}±15.21	69.8^{b}±3.89

Means within columns which followed by different letters are significantly different at 0.05 level of probability according to DMRT.

Table 2. Effect of parity number on macro-minerals content of camel milk

Production System	Location	Parity order	Minerals content of camel milk (mg/100g)				
			Ca	Na	Mg	K	P
Nomadic	North Darfur	1 – 2	110.0^{ab}±4.1	132.7^{a}±11.5	26.9^{a}±2.2	302.9^{a}±28.4	70.6^{a}±2.1
		3 – 4	115.1^{a}±3.1	160.6^{a}±6.1	21.2^{a}±1.5	340.2^{a}±16.2	64.6^{a}±2.2
		> 4	102.9^{b}±3.2	139.6^{a}±9.4	26.1^{a}±3.4	323.9^{a}±19.7	67.6^{a}±2.6
Semi-nomadic	Green Valley	1 – 2	153.0^{a} ±3.4	241.6 ^{a} ±14.7	26.8^{a}±1.3	194.6^{a}±19.5	77.1^{a}±2.2
		3 – 4	153.3^{a} ±3.5	195.2^{a}±10.4	24.0^{ab}±1.4	211.7^{a}±15.5	78.3^{a}±2.0
		> 4	162.7^{a} ±4.8	207.4^{a}±20.5	20.0^{b}±2.3	196.1^{a}±18.7	74.2^{a}±4.8
Semi-nomadic	Hamad well	1 – 2	123.2^{a}±12.2	195.6^{a}±19.3	44.2^{a}±4.7	291.3^{a}±18.9	67.2^{a}±2.7
		3 – 4	113.0 ^{a} ±6.2	182.5^{a}±24.0	37.0^{a}±2.9	252.4^{a}±27.9	65.0^{a}±4.9
		> 4	116.0^{a} ±6.6	179.8^{a}±15.5	37.8^{a}±3.2	309.7^{a}±34.9	73.0^{a}±5.2
Intensive	El Huda	1 – 2	122.3^{a} ±2.7	161.1^{b}±8.0	27.8^{a}±3.3	239.7^{a}±18.1	75.0^{a}±4.6
		3 – 4	124.8^{a}±3.6	202.7^{ab}±24.8	37.7^{a}±2.5	204.7^{a}±23.8	66.1^{a}±6.4
		> 4	125.3^{a}±2.7	279.7^{a}±105.9	36.0^{a}±6.0	206.2^{a}±55.9	69.7^{a}±10.8

Means within columns which are followed by different letters are significantly different at 0.05 level of probability according to DMRT.

On the other hand, only the Ca and K content of milk revealed significant differences due to variations in camel age, reared in the semi-nomadic (Hamad well) and intensive (El Huda) systems at Khartoum State, respectively.

4. Discussion

In this study, all camel milk samples examined showed high variations in the minerals content depending on production systems (Table 1), parity numbers (Table 2), stages of lactation (Table 3) and the age of camels (Table 4). These findings were in line with those reported previously (Deeba et al., 2020; El Amin et al., 2006; Elhassan et al., 2016; Mostafa et al., 2017). Their findings indicated that the mineral contents showed high variations according to production systems, parity orders, stages of lactation and age of camels. Also, the mineral contents of camel milk could also be affected by other factors (e.g., breeds, geographical location, feeding habits and calving number (Aludatt et al. 2010; Konuspayeva et al. 2009).

The milk obtained from camels reared in the traditional nomadic (North Darfur State), semi-nomad and intensive (Khartoum State) systems revealed significant variations in the macro-minerals (Ca, Na, Mg, K and P) content (Table 1). The obtained results are supported by findings of Elhassan et al. (2016), they found that the management systems were significantly (P≤0.05) affecting the content of Ca, Na, K and P in camel milk samples. Mostafa et al. (2017) also mentioned that Na and K contents in camel milk, under the pastoral system, were significantly higher, however, P and Mg contents were significantly lower than those from the farm system.

Macronutrient contents in the camel milk samples used in this study are in agreement with the results reported by Nikkhah (2011). They reported that camel milk has greater Cu, Fe, K, Mn, Na, and Zn. Similarly, Elhassan et al. (2016) also reported similar ranges of Ca (131.1–151.2 mg / 100g), K (196.1–228.2 mg / 100g), Na (130.3–202.1 mg / 100g), and P (79.9–100.3 mg / 100g) contents in the camel milk.

Table 3. Effect of stage of lactation on macro minerals content of camel milk

Production System	Location	Lactation Stage		Minerals content of camel milk (mg/100g)				
				Ca	Na	Mg	K	P
Nomadic	North Darfur	Early	1 – 4	108.0^{b}±3.5	149.7^{a}±8.3	27.8^{a}±2.8	309.9^{a}±24.4	69.3^{a}±2.3
		Mid	5 – 8	124.0^{a}±6.6	140.5^{a}±15.6	22.5^{a}±2.8	328.3^{a}±28.3	66.5^{a}±4.1
		Late	< 8	108.4^{b}±2.5	151.1^{a}±6.6	21.8^{a}±1.3	335.1^{a}±17.1	65.7^{a}±1.8
Semi-nomadic	Green Valley	Early	1 – 4	158.7^{a}±2.6	217.9^{ab}±10.8	23.4^{a}±1.04	180.4^{b}±13.3	78.0^{a}±1.8
		Mid	5 – 7	147.6^{a}±4.1	195.1^{b}±15.6	26.4^{a}±1.66	248.6^{a}±22.5	79.7^{a}±2.6
		Late	< 7	150.4^{a}±7.6	249.3^{a}±22.9	25.9^{a}±3.87	207.7^{ab}±18.6	67.8^{b}±3.7
Semi-nomadic	Hamad well	Early	1 – 5	115.6^{ab}±6.5	197.4^{a}±20.1	38.1^{ab}±3.0	276.2^{a}±25.4	66.9^{a}±3.9
		Mid	6 –10	107.4^{b}±6.1	177.0^{a}±18.2	44.2^{a}±3.4	265.2^{a}±25.3	70.1^{a}±3.8
		Late	< 10	136.0^{a}±11.3	169.6^{a}±12.5	32.4^{b}±3.6	339.6^{a}±49.6	70.5^{a}±9.0
Intensive	El Huda	Early	1 – 4	121.6^{a}±2.1	159.6^{b}±7.7	30.2^{a}±3.1	232.7^{a}±16.6	82.1^{a}±3.9
		Mid	5 – 7	130.0^{a}±4.7	274.7^{a}±70.0	40.8^{a}±3.3	214.6^{a}±35.4	67.8^{ab}±9.3
		Late	< 7	124.0^{a}±4.9	216.4^{ab}±41.1	35.6^{a}±3.3	193.0^{a}±38.2	50.5^{b}±6.5

Means within columns which followed by different letters are significantly different at 0.05 level of probability according to DMRT.

Table 4. Effect of camel age on the minerals content of camel milk

Production System	Location	Camel Age (years)		Minerals content of camel milk (mg/100g)				
				Ca	Na	Mg	K	P
Nomadic	North Darfur	Young	5 – 8	$109.5^{a}\pm3.1$	$139.5^{a}\pm8.6$	$25.4^{a}\pm1.7$	$323.3^{a}\pm22.9$	$69.4^{a}\pm1.7$
		Mid	9 – 12	$116.0^{a}\pm3.7$	$150.4^{a}\pm8.8$	$22.7^{a}\pm2.0$	$308.4^{a}\pm20.0$	$63.5^{a}\pm3.1$
		Old	< 12	$108.0^{a}\pm4.8$	$160.7^{a}\pm8.6$	$22.6^{a}\pm2.8$	$355.6^{a}\pm19.0$	$67.8^{a}\pm2.1$
Semi-nomadic	Green Valley	Young	2 – 6	$152.6^{a}\pm3.6$	$225.1^{a}\pm13.3$	$26.3^{a}\pm1.4$	$181.2^{a}\pm21.0$	$77.8^{a}\pm2.6$
		Mid	7 – 10	$158.1^{a}\pm3.2$	$215.7^{a}\pm12.4$	$22.6^{a}\pm1.3$	$214.7^{a}\pm14.2$	$77.1^{a}\pm2.0$
		Old	< 10	$146.7^{a}\pm4.8$	$194.7^{a}\pm20.5$	$27.2^{a}\pm1.9$	$206.3^{a}\pm25.0$	$76.0^{a}\pm3.7$
Semi-nomadic	Hamad well	Young	4 – 6	$132.8^{a}\pm9.3$	$171.6^{a}\pm26.7$	$34.6^{a}\pm1.7$	$275.4^{a}\pm35.0$	$64.0^{a}\pm3.2$
		Mid	7 – 9	$123.2^{ab}\pm10.9$	$191.6^{a}\pm8.0$	$44.2^{a}\pm4.8$	$321.5^{a}\pm36.1$	$78.2^{a}\pm6.1$
		Old	< 9	$105.6^{b}\pm4.4$	$187.8^{a}\pm18.2$	$38.9^{a}\pm3.0$	$271.6^{a}\pm25.4$	$66.4^{a}\pm4.1$
Intensive	El Huda	Young	5 – 9	$122.2^{a}\pm2.2$	$197.8^{a}\pm18.1$	$32.7^{a}\pm2.7$	$253.3^{a}\pm15.4$	$74.2^{a}\pm5.1$
		Mid	10 –14	$126.7^{a}\pm5.4$	$163.0^{a}\pm27.3$	$35.2^{a}\pm3.6$	$156.3^{b}\pm27.9$	$61.7^{a}\pm7.2$
		Old	< 14	$125.3^{a}\pm2.7$	$279.7^{a}\pm105.9$	$36.0^{a}\pm6.0$	$206.2^{ab}\pm55.9$	$69.7^{a}\pm10.8$

Means within columns which followed by different letters are significantly different at 0.05 level of probability according to DMRT.

Dromedary milk contain considerable mineral contents, e.g., Ca (114, mg/100g), Na (59, mg/100g), K (156, mg/100g) and Mg (10.5 mg/100g) (Al Haj and Al Kanhal, 2010). Ca content of mature camel milk varied from 32.5 to 126.9 (mg/100g), Mg from 1 to 6.9 mg/100g, Na from 14.8 to 71.1 mg/100g, K from 50.9 to 186.2 mg/100g and inorganic phosphate from 10 to 54.4 mg /100g (Omer and Eltinay, 2008). Al-Juboori et al. (2013) reported mean ash value of 0.48±0.05% in the camel milk. The overall mean values (%) were 0.19±0.01 K, 0.14±0.02 Na, 0.11±0.02 Ca, 0.05±0.01 P and 0.03±0.02 for sulphur. The mean values for Mg, Na, K and Ca content of dromedary camel milk ($100g^{-1}$) revealed 10.5, 59, 156 and 114 mg, respectively (Jilo and Tegegne, 2016).

The camels grazed in the nomadic system at Darfur State revealed higher value for milk K (317.8±12.17 mg/100g) content than those reported previously (Al Haj and Al Kanhal, 2010; Elhassan et al., 2016; Al-Juboori et al., 2013; Konuspayeva et al., 2008). Camels are feed on trees and shrubs, which are rich source of protein, Ca and P. However, these contents gradually decrease upon drying and reaching to maturity (Deeba et al., 2020). However, Ca, P, and Mg in grasses and browsing trees recorded different values in Darfur region (Mustafa et al., 2014). Contrarily, Shamat (2008) found that mineral contents in camel serum and tissues varied in East and West Sudan according to feeding, locations and seasons. Additionally, the highest means of K (252.4 to 355.6 mg/100 g) were recorded for milk of the camels reared in the traditional nomadic system (North Darfur) and semi-nomadic (West Omdurman) systems. These findings were supported by the results of Shamat, (2008) who found that the Na and K content were higher in the serum of camels grazed in Darfur than that found in eastern parts of Sudan.

The present result of macro-mineral contents of camel milk from different locations, is supported by the findings of Aludatt et al. (2010). They found the regional anomalies in the mineral contents in camel milk collected from different parts of Jordan. Furthermore, different breeds were reared in the North Darfur and Khartoum states. These variations can be attributed to genotypic differences It was stated previously that the variations in mineral contents were due to different breeds (Jilo and Tegegne, 2016; Mehaia et al., 1995; Zhao et al., 2015).

Three parity orders shown in different locations were not significantly affecting the minerals content of camel milk (Table 2). Meanwhile highly significant variations were recorded in Ca, Na and Mg content of milk samples collected from nomadic (North Darfur), intensive (West Omdurman, Khartoum State) and semi-nomadic (East Nile, Khartoum State) production systems according to the parity orders of she-camels. The present findings are in line with those reported by Elhassan et al. (2016) who mentioned that Ca, K and P content were not affected by the variation of parity orders. However, the Na content was increased significantly in the fourth and fifth parity order than that of parity ranged from the first to the third. El-Amin et al. (2006) found that the ash and Na contents of camel milk were not affected by the variations in the parity number. Mostafa et al. (2017) reported that the Ca and P content increased significantly, up to the 7-8 parities, while Na (up to 5-6 parities) and K (up to 3-4 parities) increased significantly. However, there was no significant influence of parity order on the Mg content.

Calcium content of milk samples from she-camels browsing in the nomadic (North Darfur State) and semi-nomadic (Hamad well, Khartoum State) systems were affected significantly by the stages of lactation

(Table 3). These findings are in line with the results reported by Elhassan et al. (2016). In Table 3 the early, mid and late lactation stages were found to significantly influence Na and P contents of milk samples from she-camels kept in semi-nomadic (East Nile) and intensive systems in Khartoum State. The Na content of camel milk was reported previously to be affected by the variation of lactation stage (El-Amin et al., 2006). Moreover, Elhassan et al. (2016) mentioned that the milk Na contents were significantly affected by the lactation stage, but no effect was observed on the values of P in camel milk.

The early, mid and late stages of lactation significantly influenced the K and Mg contents in the camel milk samples collected from the semi-nomadic systems at Omdurman and East Nile areas (Khartoum State), respectively (Table 3). Elhassan et al. (2016) reported that lactation stage significantly induced variations of K contents in camel milk. The minimal values for Ca and P (1.43 g/l and 1.16 g/l) were found at the beginning of the lactation (Konuspayeva et al., 2010). Moreover, Riyadh et al. (2012) reported lactation stage to cause variations in mineral contents.

The non-significant variations of the macro-mineral contents of the milk samples can be attributed to variations in the age of camels that browse in the nomadic systems at North Darfur and the semi-nomadic of East Nile at Khartoum State (Table 4) might be because of the ability of the camels to select their feed from the natural pastures. However, the significant differences in the Ca and K content of milk, because of the variations of camel age that kept in Western Omdurman (Khartoum State) for both semi-nomadic and the intensive systems could be due to the restricted ration, especially for the group kept in the intensive system. This supported Deeba et al. (2020) who reported high variations in Ca, P and other mineral contents of camel milk could be attributed to some factors, among which is the age of she-camels and its food quality. Significant variations in the milk mineral contents can be due to the differences in water intake, feeding behavior and different breeds (Jilo and Tegegne, 2016).

5. Conclusion

In this study all camel milk samples examined showed high variations in the macro-mineral contents depending on type of the production systems, which are practiced in the different locations. The availability of water and differences in feed types and sources are the main contributing factors of this variation. Other factors including breed, parity orders, lactation stages and age of she-camels might influence the macro-minerals levels in camel milk.

List of Abbreviation: ANOVA, Analysis of Variance; AOAC, Association of Official Analytical Chemist Analytical Chemist; Ca, Calcium; Cu, Copper; Fe, Iron; K, Potassium; Mg, Magnesium; Mn, Manganese; MOARF, Ministry of Animal Resource and Fisheries; Na, Sodium; P, phosphorus; SPSS, Statistical Package for Social Sciences; Zn, Zinc.

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Authors Contribution: **S**.M.B.M.E. and H.I.O.: Conceived idea, designed experiment and protocol, conducted laboratory work and investigation, data analysis, and writing the original draft of the article. I.E.M.E.: The idea, protocol designing, supervision, writing–review and editing the final version of the article. All authors approved the manuscript.

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