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Research Article

Milk Composition, Production, and Reproduction Performance of Local and Exotic Dairy Goats in Khartoum State, Sudan

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ABSTRACT

Introduction: Sudan is known as home to a diverse range of goat breeds, among which the Nubian goat holds significant importance as a dairy producer. Recently, the country imported several exotic dairy goat breeds. The study aimed to describe the production and reproduction performance of Nubian, Damascus, Mazain, and Alpine goats kept in Khartoum State, Sudan. In addition, this study assesses solids not fat (SNF), fat, protein, casein, whey proteins, and lactose in the milk of these breeds.
Materials and methods: Information about the production performance of goat farms found in Khartoum State was obtained through personal interviews with owners and available records. A total of 145 milk samples were collected from the investigated goat breeds and analyzed for their content. The milk SNF, fat, protein, lactose, casein, and whey proteins were determined in the collected samples.
Results: Significant differences among exotic breeds for birth weight of kids, body weight of dams**,** milk yield, and lactation length were indicated. The fat content was significantly different among goat breeds. The lower fat content of the milk was recorded in Alpine compared to other goats. The protein contents indicated 3.58 ± 0.08%, 3.52 ± 0.12%, 3.62 ± 0.09%, and 3.33 ± 0.07% in the Nubian, Damascus, Mazain, and Alpine goat breeds, respectively. The casein and whey protein content were high in the milk of the Mazain goat, whereby some higher values of casein and whey protein were obtained during the 5-6 months of lactation in the Mazain goat compared to other goats. The lactose content of milk indicated higher values during the first two months of lactation in all goats. The SNF content of milk showed higher values in Damascus and Mazain compared to Alpine goats, which showed significant differences during the progress of lactation in all goats.
Conclusion: It is concluded that variations were found regarding the chemical composition of milk and performance in different breeds of goats in Khartoum State, Sudan.

1. Introduction

Milk is the most valuable food due to its unique composition and nutritional value[1]. Milk is a rich source of essential nutrients, such as proteins, fats, lactose, vitamins, micro- and macro-elements, and enzymes that are crucial for supporting the proper growth, development, and essential functions of the human body[2].

Due to the higher demand for dairy goat products for human consumption, the importance of dairy goats increased in the last decades. Some key factors, including the greater breed diversity (> 500 breeds) and their capacity to adapt to harsh conditions in most environments lead to the success of the goat industry[3]. Despite the considerable tolerance to harsh climatic or geographical conditions and cheap care costs, dairy goats are viable livestock species for marginal and landless farmers[4].

Dairy goats have been traditionally used for milk

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production all over the world, particularly in Asia, Africa, and Europe that are producing 58.4%, 24.1%, and 14.2% of the world's goat milk, respectively[5]. Dairy goats with high-yielding genotypes are mainly located in Europe[6]. Sudan has an average goat milk yield of about 64 kg per year, whereas India's average is over 179 kg per year.

The goat breeds vary significantly in their productivity and milk composition[7]. Milk production traits play a fundamental role in livestock production and the related economy[8]. Information on the yield and nutritional composition in milk is vital to promote the right formulation of feeds for goat kids and as food for humans, especially infants[9]. Factors, such as sex, birth weight, litter size, parity, and milk yield significantly influenced the average daily weight gain and survival rate of suckling Zaraibi kids in the pre-weaning stage[10].

Several factors, including the animal species, breed, and diet influence the milk composition[11]. The nutritional and functional properties and health-promoting benefits of goat milk are due to its rich content of biologically active constituents, specifically peptides derived from its proteins, which can help to prevent chronic diseases as well as maintain gastrointestinal health[12].

The Damascus goat is a native breed of Syria that was thought to have originated near Damascus, Syria, then they are introduced to countries as it is primarily originated in Syria, Lebanon, and Cyprus[13]. Damascus goats showed a higher potentiality for milk production and a long lactation period under subtropical environmental conditions[14].

The fat and protein contents in the milk of the Alpina breed revealed 3.33% and 3.16%[15], respectively. The average goat milk composition revealed 12.6% total solids, 4.0% fat, 3.3% protein, 4.3% lactose, and 0.8% ash[16]. In Sudan, 13.49 ± 0.084% total solids, 9.11 ± 0.049% solids not fat (SNF), 3.59 ± 0.03% total protein, 2.87 ± 0.025% casein, 0.72 ± 0.007% whey proteins, 0.19 ± 0.01 mg/1000g albumin, and 0.27 ± 0.003 mg/1000g β-lactoglobulin were reported[17]. These values were higher during the early stage of lactation and then decreased towards the mid-lactation stage[17]. The milk composition of goats in Khartoum State revealed total solids of 14.6 ± 0.057%, moisture of 87.71 ± 0.07, lactose of 3.79 ± 0.7%, fat of 3.9 ± 0.12%, protein of 4.81 ± 0.12, pH of 6.47 ± 0.05, acidity of 0.153 ± 0.03%, and ash of 0.899 ± 0.034%[1].

The Nubian goat is a native dairy goat in Sudan, however, recently some exotic dairy goats were introduced to Sudan. The present study aimed to investigate the performance of dairy goats raised in Khartoum State and to study the effect of the progress of lactation and parity order on changes in the chemical composition of goat milk from Nubian and exotic goat breeds that were kept in Khartoum State, Sudan.

2. Materials and Methods

2.1. Ethical approval

This study was conducted according to the institutional animal care and use stated by committee guidelines of Khartoum university, Sudan. The faculty of animal production research board approved this study.

2.2. Locations and animal breeds

In the current study, field sampling was conducted from April to July 2017 in two sites. The first location was Animal Production Research Center, Khartoum Office, which was established with the support of American aid in 1963 under the general administration of Animal Production at the Ministry of Animal Resources and Fisheries (Animal Production Research Centre). Meanwhile, the second site was Al-nawader farm for agriculture and animal production (private goat breeding) which was located in Silate, which has been in the East Nile region since 2015.

A total of 145 animals were used in the present study, including 30 Nubian goats from the Animal Production Research Centre farm at Kuku, 40 Damascus, 45 Mazain (Damascus goats raised in Cyprus), and 30 Alpine goats from Al-nawader farm, Silate. Both farms are located in East Nile Provence, Khartoum State, Sudan.

2.3. Data collection

Data regarding the rearing system utilized in the chosen farms within Khartoum State was gathered through personal interviews conducted with the owners of the goats. Moreover, information was also collected from records. In the selected farms (Animal Research Center, Hillat Kuku, and Al-nawader) the obtained information included general management, breeding practices, and the structure of herds.

2.4. Live weight

Live weight (kg) was taken for the does and their kids at birth and weaning (2 to 3 months).

2.5. Milk yield

The milk yield of the does that was recorded in kilograms was obtained from records.

2.6. Collection of goat milk samples

The milk samples were collected from 145 female goats on the farms using hand. Composite milk samples (100 ml) were collected in dry clean bottles. The samples were labeled and transferred in iceboxes to the dairy biochemistry laboratory of the faculty of animal production, university of Khartoum, Sudan for chemical analysis.

2.7. Chemical analysis of milk

The milk constituents (SNF, fat, protein, and lactose) of the milk samples were determined monthly for up to 6 months using the milk analyzer Lactoscan 90 according to

the manufacturer instructions (Milkotronic LTD, Nova Zagora, Bulgaria).

2.8. Determination of casein and whey proteins

The analysis was carried out using the Kjeldahl method[18,19].

2.9. Statistical analysis

The general information about the goat's performance was analyzed using Statistical Package for Social Science (SPSS) version 16[20] and descriptive statistics procedures were obtained. Milk constituents and protein fractions were analyzed using the General Liner Model (GLM) procedure in SPSS version 16[20]. Differences between means were calculated using Duncan's Multiple Range Test (DMRT) for significant differences ($p < 0.05$).

3. Results

3.1. Performance and reproductive traits of dairy goats in Khartoum State

3.1.1. Some productive and reproductive traits of Nubian goats

In the present study kids of Nubian goats were born with a mean birth weight of 2.80 ± 0.18 kg. The mean body weight of dams revealed 50.5 ± 1.21 kg, while the mean for does at first matting was 9.5 ± 0.17 months. The mating system for Nubian goats is natural mating. The mean age for does at first kidding was 13.5 ± 0.29 months and the mean period between kidding was 8.5 ± 0.37 months (Table 1).

The mean litter size of Nubian goats was 1.70 ± 0.61 and the mean milk yield during the lactation period was 249 ± 0.83 kg and the milking was practiced twice a day. The mean period between kidding was 8.5 ± 0.67 months and the mean lactation length for does was 150 ± 1.15 days (Table 1).

3.1.2. Some productive and reproductive traits of goats kept at Al-nawader farm

As can be seen in Table 2, the means of birth weight of the kids was significantly higher in the Damascus goat (3.72 ± 0.54) and Mazain goat (3.73 ± 0.55 kg), compared to that of the Alpine goat breed (3.35 ± 0.52 kg) ($p < 0.05$).

The mean body weight of the dams revealed a mean of 60.5 ± 1.55 kg for Damascus, 63.0 ± 1.15 kg for Mazain, and 55.3 ± 1.35 kg for Alpine goat breeds (Table 2).

The does at first matting revealed a mean of 11.3 ± 0.70 months for Damascus, 12.1 ± 0.81 months for Mazain, and 12.2 ± 0.51 months for Alpine goat breeds (Table 2).

The mating system for all breeds on the farm is natural mating. The mean age for does at first kidding was 16.5 ± 0.75 months for Damascus, 17.5 ± 0.67 months for Mazain, and 17.3 ± 0.72 months for Alpine goats (Table 2). The means of litter size showed 1.73 ± 1.60 for Damascus, 1.75 ± 0.71 for Mazain, and 1.73 ± 0.69 for Alpine goats (Table 2).

Table 1. Some productive and reproductive traits of Nubian goat breeds in Animal Research Center, Hillat Kuku, Khartoum State, Sudan

Measurements	Mean ± SD	Minimum	Maximum
Birth weight (kg)	2.80 ± 0.18	2.15	3.22
Body weight of the dams (kg)	50.5 ± 1.21	53	55.2
Age at first mating (month)	9.5 ± 0.17	7.5	10
Age at first kidding (month)	13.5 ± 0.29	12.2	16
Kidding intervals (month)	8.5 ± 0.37	7.3	9.2
Litter size	1.70 ± 0.61	1.65	1.78
Milk yield (kg)	249 ± 0.83	243	275
Lactation length (days)	150 ± 1.15	140.3	155

During the lactation period, the means of milk yield for Damascus was 355 ± 0.50 kg, for Mazain 377 ± 0.45 kg, and for Alpine goats 389 ± 0.38 kg (Table 2). Goat breeds on this farm were milked twice a day. The mean period between kidding was 12.2 ± 0.13 months for Damascus, 12.5 ± 0.15 months for Mazain, and 12.1 ± 0.16 months for Alpine goats. The average lactation duration for does was found 275 ± 1.32 days for Damascus, 210 ± 1.23 days for Mazain, and 230 ± 2.16 days for Alpine goats (Table 2).

Table 2. Some productive and reproductive traits of different breeds of goat (Damascus, Mazain, and Alpine) reared in Alnwader farm at Khartoum State, Sudan

Measurements	Damascus	Mazain	Alpine
Birth weight (kg)	3.72^{a} ± 0.54	3.73^{a} ± 0.55	3.35^{b} ± 0.52
Body weight of dams (kg)	60.5^{a} ± 1.55	63.0^{a} ± 1.15	55.3^{b} ± 1.35
Age at first mating (month)	11.3^{b} ± 0.70	12.1^{a} ± 0.81	12.2^{a} ± 0.51
Age at first kidding (month)	16.5^{b} ± 0.75	17.5^{a} ± 0.67	17.3^{a} ± 0.72
Kidding intervals (month)	12.2^{a} ± 0.13	12.5^{a} ± 0.15	12.1^{a} ± 0.16
Litter size	1.73^{a} ± 1.60	1.75^{a} ± 0.71	1.73^{a} ± 0.69
Milk yield (kg)	355^{b} ± 0.50	377^{a} ± 0.45	389^{a} ± 0.38
Lactation length (days)	275^{a} ± 1.32	210^{b} ± 1.23	230^{b} ± 2.16

Mean data ± Standard deviation. ^{a,b}Means different superscript letters in a row are significantly different ($p < 0.05$)

Table 3. Milk components for Nubian goats and exotic goat breeds kept in Khartoum State, Sudan

Variables	Nubian	Damascus	Mazain	Alpine
Fat (%)	4.82 ± 0.24	4.47^{a} ± 0.13	4.53^{a} ± 0.22	3.55^{b} ± 0.21
Protein (%)	3.58 ± 0.08	3.52^{a} ± 0.12	3.62^{a} ± 0.09	3.33^{a} ± 0.07
Casein (%)	2.84 ± 0.08	2.81^{a} ± 0.16	2.86^{a} ± 0.09	2.66^{a} ± 011
Whey protein (%)	0.70 ± 0.13	0.70 ^{a} ± 0.08	0.71^{a} ± 0.12	0.67^{b} ± 0.15
Solid not fat (%)	8.89 ± 0.16	9.12^{a} ± 0.09	9.08^{a} ± 0.07	8.53^{b} ± 0.08
Lactose (%)	4.78 ± 0.09	4.76^{a} ± 0.17	4.82^{a} ± 0.13	4.54^{b} ± 0.08

Mean data ± Standard deviation. ^{a,b}Means different superscript letters in a row are significantly different ($p < 0.05$)

3.1.3. Chemical composition of Nubian, Damascus, Mazain, and Alpine goat breeds

The SNF, fat, protein, casein, whey proteins, and lactose contents of milk collected from Nubian revealed 8.89 ± 0.16%, 4.82 ± 0.24%, 3.58 ± 0.08%, 2.84 ± 0.08%, 0.7 ± 0.13%, and 4.78 ± 0.09%, respectively (Table 3).

3.2. Solids not fat content

The SNF content indicated higher values in the milk of Damascus (9.12 ± 0.09%) and Mazain (9.08 ± 0.07%) goats compared to the Nubian (8.89 ± 0.16%) and Alpine (8.53 ± 0.08%) goats (Table 3).

As can be seen in Tables 4, 5, 6, and 7, the SNF content of milk values significantly differs during the progress of lactation in some parities for goat breeds ($p < 0.05$). However, the overall SNF content means of milk was not significantly different for all parities in all goat breeds ($p > 0.05$, Tables 4, 5, 6, and 7).

3.3. Fat content

The milk obtained from Nubian goats showed a fat content of 4.82 ± 0.24% (Table 3). The fat content of milk collected from Damascus, Mazain, and Alpine goats was measured at 4.47 ± 0.13%, 4.53 ± 0.22%, and 3.55 ± 0.21%, respectively (Table 3). The milk fat levels were found to be higher in Damascus and Mazain goats, whereas Alpine goats showed notably lower fat content in comparison to other breeds ($p < 0.05$).

Table 4 indicates the mean fat content varied among the first 6 months of lactation. The overall mean fat content was not significantly different (4.60 ± 0.36%, 4.79 ± 0.23%, 4.29 ± 0.24 %, and 5.18 ± 0.31%) for the second, third, fourth, and fifth parities of Nubian goat breed, respectively ($p > 0.05$) (Table 4). In addition, the result in Tables 5, 6, and 7 shows nonsignificant values for milk fat during the first 6 months of lactation in all parities for the studied goat breeds except during the first stages of lactation ($p > 0.05$) (Tables 5, 6, and 7).

3.4. Protein content

The obtained means content of milk protein varied among the 4 goat breeds. As can be seen in Table 3, there are nonsignificant differences in milk protein among goat breeds ($p > 0.05$). The protein content revealed 3.52 ± 0.12%, 3.62 ± 0.09%, 3.58 ± 0.08%, and 3.33 ± 0.07% for the Damascus, Mazain, Nubian, and Alpine goats (Table 3).

The protein content of milk during the first 6 months of lactation was not significantly different during the second parity for the Nubian goat (Table 4) and during the second and fourth parity in the Damascus goat (Table 5), during all parities for Mazain goat (Table 6), and the second, third and fifth parites in Alpine goat ($p > 0.05$, Table 7). However, in some parities of these goat breeds, the protein values of milk showed significant differences ($p <0.05$). Meanwhile, the overall means for the protein content of the milk were not significantly different in the second, third, fourth, and fifth parities in all goat breeds ($p > 0.05$) (Tables 5, 6, and 7).

Table 4. Milk components (%) of Nubian goats in different parity orders and stages of lactation reared in Khartoum State, Sudan

Parity order	Stage of lactation/month	Fat	SNF	Protein	Casein	Whey Protein	Lactose
	(1-2)	4.31^{b}±0.42	9.08^{a} ±0 14	3.50^{a} ±0.05	2.80^{a} ±0.09	0.69^{a} ±0.09	4.79^{a} ±0.17
2	(2-4)	4.81^{a} ±0.30	9.08^{a} ±0.13	3.59^{a} ±0.13	2.84^{a} ±0.12	0.70^{a} ±0.11	4.67^{b} ±0.15
	(4-6)	4.68^{a}±0.21	9.57^{a} ±0.08	3.67^{a} ±0.15	2.92^{a} ±0.13	0.71^{a} ±0.12	4.70^{a} ±0.13
Overall means		4.60^{a} ±0.36	9.12^{a} ±0.08	3.60^{a} ±0.22	2.86^{a} ±0.32	0.71^{a} ±0.21	4.77^{a} ±0.23
	(1-2)	4.82^{a} ±0.52	9.13^{b}±0.09	3.56^{b} ±0.12	2.83^{b}±0.01	0.70^{a}±0.08	4.71^{a} ±0.15
3	(2-4)	4.96^{a} ±0.35	9.26^{b}±0.13	3.63^{a} ±0.14	2.89^{b} ±0.04	0.71^{a}±0.16	4.81^{a} ±0.16
	(4-6)	4.73^{a} ±0.12	9.97^{a} ±0.49	3.79^{a} ±0.36	3.01^{a} ±0.47	0.77^{a} ±0.79	4.91^{a} ±0.21
Overall means		4.79^{a} ±0.23	9.32^{a} ±0.29	3.68 ^{a}±0.16	2.91^{a} ±0.21	0.70^{a} ±0.37	4.89^{a} ±0.38
	(1-2)	4.07^{a} ±0.16	9.21^{a} ±0.09	3.51^{b} ±0.13	2.79^{b}±0.11	0.68^{b} ±0.22	4.78^{a} ±0.22
4	(2-4)	4.03^{a} ±0.16	9.25^{a} ±0 10	3.64^{a} ±0.14	2.90^{a}±0.13	0.71^{a} ±0.017	4.82^{a} ±0.17
	(4-6)	4.52 ^{a} ±0.15	8.48^{b} ±0.30	3.64^{a} ±0.18	2.91^{a}±0.15	0.72^{a} ±0.22	4.61^{b} ±0.06
Overall means		5.83^{a} ±0.26	8.85^{a} ±0.16	3.57^{a} ±0.33	2.86^{a} ±0.32	0.70^{a} ±0.42	4.71^{a}±0.23
	(1-2)	5.83^{a} ±0.26	8.45^{a} ±0.35	3.45^{b} ±0.13	2.59^{b} ±0.12	0.68^{a} ±0.09	4.73^{a}±0.15
5	(2-4)	5.14^{b}±0.17	9.11^{a} ±0.12	3.59^{a} ±0.09	2.87^{a} ±0.13	0.70^{a} ±0.10	4.80^{a} ±0.16
	(4-6)	5.94^{a} ±0.09	9.30^{a} ±0.14	3.65^{a} ±0.14	2.92^{a} ±0.11	0.71^{a} ±0.12	4.81^{a} ±0.12
Overall means		5.18^{a} ±0.31	8.86^{a} ±0.17	3.57^{a} ±0.32	2.86 ^{a} ±0.27	0.70^{a} ±0.23	4.70^{a} ±0.33

Mean data ± Standard deviation. ^{a,b}Means different superscript letters in a column are significantly different ($p < 0.05$)

Table 5. Milk components (%) of Damascus goats in different parity orders and stages of lactation reared in Khartoum State, Sudan

Parity order	Stage of lactation/month	Fat	SNF	Protein	Casein	Whey Protein	Lactose
	(1-2)	4.25^{b}±0.23	9.09^{b}±0.07	3.47^{a}±0.13	2.73^{a}±0.15	0.69^{a}±0.12	4.80^{a}±0.16
2	(2-4)	4.39^{a}±0.21	9.20^{a}±0.10	3.55^{a}±0.12	2.80^{a}±0.15	0.70^{a}±0.12	4.78^{a}±0.13
	(4-6)	4.42^{a}±0.31	9.25^{a}±0 14	3.56^{a}±0.14	2.86^{a}±0.13	0.70 ^{a} ±0.11	4.70^{b} ±0.14
Overall means		4.36^{a}±0.14	9.19^{a} ±0.17	3.52^{a}±0.13	2.79^{a}±0.13	0.70^{a} ±0.12	4.78^{a} ±0.013
	(1-2)	4.43^{a}±0.42	9.12^{b}±0.21	3.46^{b}±0.13	2.71^{b}±0.11	0.69^{b}±0.11	4.95^{a}±0.16
3	(2-4)	4.18^{a}±0.47	9.36^{a}±0.08	3.58^{a}±0.13	2.89^{a}±0.11	0.71^{a}±0.11	4.85^{a}±0.13
	(4-6)	4.55^{a}±0.33	9.19^{a}±0.11	3.57^{a}±0.17	2.85^{a}±0.11	0.71^{a}±0.17	4.77 ^{b}±0.29
Overall means		4.32^{a}±0.24	9.20^{a} ±0.09	3.53^{a}±0.13	2.82^{b}±0.17	0.70^{b}±0.13	4.80 ^{a}±0.18
	(1-2)	4.53^{a}±0.23	9.15^{a}±0.17	3.47^{a}±0.14	2.73^{a}±0.25	0.69^{a}±0.12	4.87^{a}±0.12
4	(2-4)	4.65^{a}±0.22	9.06^{b}±0.21	3.49^{a}±0.13	2.79^{a}±0.14	0.69^{a}±0.14	4.72 ^{b}±0.05
	(4-6)	4.76^{a}±0.13	9.42^{a}±0.19	3.61^{a}±0.11	2.91^{a}±0.19	0.71^{a}±0.13	4.70 ^{b}±0.01
Overall means		4.64^{a}±0.24	9.10^{a}±0.16	3.51^{a}±0.12	2.80^{a}±0.28	0.70^{a}±0.13	4.77^{a}±0.22
	(1-2)	4.03^{b}±0.35	8.87^{a}±0.08	3.45^{b}±0.13	2.70^{b}±0.19	0.69^{a}±0.14	4.76^{a}±0.05
5	(2-4)	4.55^{a}±0.14	9.07^{a}±0.15	3.51^{a}±0.15	2.81^{a}±0.08	0.69^{a}±0.13	4.74^{a}±0.04
	(4-6)	4.55^{a}±0.16	9.07^{a}±0.17	3.55^{a}±0.16	2.83^{a}±0.18	0.71^{a}±0.13	4.70^{a}±0.04
Overall means		4.27^{a}±0.22	8.99^{a}±0.15	3.51^{a}±0.13	2.79 ^{a} ±0.27	0.70^{a}±0.12	4.74^{a}±0.04

Mean data ± Standard deviation. ^{a,b}Means different superscript letters in a column are significantly different ($p < 0.05$). SNF: Solids not fat

3.5. Casein content

The casein content (2.84 ± 0.07%) of the Nubian goat is shown in Table 3. According to Table 3, the casein content of milk from different exotic breeds followed the same pattern as for protein content, whereby nonsignificant higher values of casein content were found.

The casein content showed higher levels in the milk during the 5th and 6th months of lactation compared to that obtained during the earlier months of lactation in all goat breeds (Tables 4, 5, 6, and 7). Moreover, the overall means for casein content of the milk were not significantly different during the second, third, fourth, and fifth parities in all goat breeds ($p > 0.05$, Tables 4, 5, 6, and 7).

3.6. Whey proteins

The whey protein content of milk from Nubian goat (0.70 ± 0.13%) is shown in Table 3, which is significantly ($p < 0.05$) higher in Mazain (0.71%) and Damascus (0.70%) goats compared to that obtained from Alpine goat (0.67%).

The whey protein of milk varied significantly among the progress of lactation in the studied goat breeds ($p < 0.05$, Tables 4, 5, 6, and 7). During the 5th and 6th months of lactation in the study, higher levels of whey protein content in milk were found.

The overall means of the whey protein content of milk revealed a nonsignificant difference for all goat breeds ($p > 0.05$, Tables 4, 5, 6, and 7).

3.7. Lactose content

According to Table 3, the lactose content of milk from the Nubian goat breed revealed 4.78 ± 0.09% with significant differences for the values obtained from Damascus (4.76 ± 0.17%) and Mazain (4.82 ± 0.13%) goats compared to that of Alpine goat (4.54 ± 0.08%, $p < 0.05$).

The lactose content indicated slightly higher values during the first 2 months of lactation in some parities for the selected goat breeds and maintained constant levels until the 6th month of lactation with nonsignificant variations ($p > 0.05$, Tables 4, 5, 6, and 7). Similarly, the overall means of milk lactose content were not significantly different for all parities in all goat breeds ($p > 0.05$, Tables 4, 5, 6, and 7).

Table 6. Milk components (%) of Mazain goats in different parity orders and stages of lactation reared in Khartoum State, Sudan

Parity order	Stage of lactation/month	Fat	SNF	Protein	Casein	Whey Protein	Lactose
	(1-2)	4.49^{b} ±0.17	9.00^{a} ±0.07	3.61^{a} ±0.18	2.04^{b}±0.12	0.68^{b} ±0.11	4.79^{a} ±0.13
2	(2-4)	4.68^{b} ±0.26	9.11^{a} ±0.14	3.62^{a} ±0.13	2.08^{b} ±0.11	0.71^{a} ±0.12	4.91^{a} ±0.16
	(4-6)	4.80^{a} ±0.42	9.23^{a} ±0 07	3.65^{a} ±0.13	2.88^{a} ±0.15	0.72^{a} ±0.11	4.70^{b} ±0.14
Overall means		4.65^{a} ±0.23	9.09^{a}±0.07	3.63^{a} ±0.22	2.85^{a} ±0.12	0.70^{a} ±0.21	4.81^{a} ±0.13
	(1-2)	4.19^{a} ±0.16	9.02^{a} ±0.17	3.61^{a} ±0.15	2.81^{a} ±0.08	0.69^{a} ±0.11	4.75^{a} ±0.13
3	(2-4)	4.85^{a} ±0.42	8.93^{a} ±0.21	3.63^{a} ±0.09	2.06^{a}±0.10	0.72^{a} ±0.07	4.87^{a} ±0.16
	(4-6)	4.76^{a} ±0.40	9.37^{a} ±0 17	3.69^{a} ±0.14	2.92^{a} ±0.11	0.72^{a} ±0.09	4.92 ^{a} ±0.17
Overall means		4.57^{a} ±0.24	9.05^{a} ±0.29	3.63^{a} ±0.23	2.85^{a} ±0.10	0.70^{a} ±0.13	4.83^{a} ±0.18
	(1-2)	4.19 ^{b} ±0.16	9.02^{b} ±0.17	3.61^{a} ±0.15	2.81^{b}±0.09	0.69^{b}±0.11	4.73 ^{a}±0.13
4	(2-4)	4.48^{a}±0.35	9.27^{a} ±0.18	3.63^{a} ±0.13	2.88^{a}±0.17	0.71^{a} ±0.22	4.87^{a} ±0.15
	(4-6)	4.76^{a}±0.40	9.37^{a} ±0 17	3.69^{a} ±0.14	2.92^{a}±0.21	0.72^{a}±0.13	4.90^{a}±0.17
Overall means		4.37^{a} ±0.22	9.19^{a}±0.25	3.64^{a}±0.23	2.86^{a}±0.21	0.70^{a}±0.23	4.81^{a} ±0.13
	(1-2)	4.56^{a}±0.28	9.06^{a}±0.16	3.60^{a}±0.13	2.87^{a}±0.14	0.70^{a}±0.12	4.89^{a}±0.16
5	(2-4)	4.56^{a}±0.28	9.06^{a}±0.16	3.60^{a}±0.13	2.87^{a}±0.14	0.70^{a}±0.12	4.89^{a}±0.16
	(4-6)	4.60^{a}±0.42	9.17^{a}±0 19	3.63^{a}±0.24	2.84^{a}±0.13	0.71^{a}±0.13	4.81^{a}±0.15
Overall means		4.48^{a}±0.23	8.09^{a} ±0.26	3.62^{a}±0.33	2.84^{a}±0.22	0.71^{a}±0.22	4.81^{a}±0.13

Mean data ± Standard deviation. ^{a,b}Means different superscript letters in a column are significantly different ($p < 0.05$). SNF: Solids not fat

Table 7. Milk components (%) of Alpine goats in different parity orders and stages of lactation reared in Khartoum State, Sudan

Parity order	Stage of lactation/month	Fat	SNF	Protein	Casein	Whey Protein	Lactose
	(1-2)	3.00b ±0.28	8.31^{a} ±0.28	3.27^{a} ±0.17	2.60^{a} ±0.15	0.67^{a} ±0.12	4.48^{a}±0.11
2	(2-4)	3.38^{a} ±0.13	8.66^{a} ±0.17	3.44^{a} ±0.14	2.72^{a} ±0.18	0.68^{a} ±0.11	4.62^{a} ±0.14
	(4-6)	3.77^{a}±0.12	8.70^{a} ±0 14	3.40^{a} ±0.14	2.67^{a} ±0.11	0.68^{a} ±0.21	4.58^{a} ±0.15
Overall all means		3.58^{a} ±0.37	8.56^{a} ±0.28	3.38^{a} ±0.33	2.67^{a} ±0.22	0.68^{a} ±0.31	4.56^{a} ±0.20
	(1-2)	3.34^{b}±0.25	8.43^{a} ±0.86	3.22^{a} ±0.09	2.60^{a} ±0.09	0.67^{b} ±0.13	4.51^{a} ±0.19
3	(2-4)	4.06^{a} ±0.17	8.61^{a} ±0.16	3.30^{a} ±0.15	2.56^{b} ±0.14	0.66^{b} ±0.12	4.50^{a} ±0.09
	(4-6)	3.84^{a} ±0.13	8.04^{b} ±0.28	3.35^{a} ±0.13	2.75^{a} ±0.16	0.69^{a} ±0.17	4.46^{b} ±0.15
Overall all means		3.41^{a} ±0.13	8.24^{a} ±0.28	3.35^{a} ±0.13	2.75^{a} ±0.26	0.69^{a} ±0.17	4.49^{a} ±0.25
	(1-2)	3.36^{b} ±0.17	6.98^{b}±0.32	3.30^{b} ±0.12	2.64^{a} ±0.10	0.67^{b}±0.22	4.47^{a} ±0.12
4	(2-4)	3.74^{a} ±0.26	8.63^{a} ±0.17	2.64^{a} ±0.10	2.59^{b} ±0.13	0.68^{a} ±0.12	4.60^{a} ±0.09
	(4-6)	4.31^{a} ±0.09	8.50^{a} ±0.17	3.26^{b} ±0.16	2.98^{a} ±0.47	0.72^{a} ±0.11	4.58^{a} ±0.11
Overall all means		3.80^{a} ±0.10	8.56^{a} ±0.31	2.59^{b} ±0.13	2.73^{a} ±0.05	0.68^{a} ±0.041	4.58^{a} ±0.22
	(1-2)	3.24^{b} ±0.16	8.44^{b}±0.22	3.34^{a} ±0.17	2.67^{a} ±0.11	0.66^{a} ±0.12	4.47^{a} ±0.8
5	(2-4)	4.04^{a} ±0.15	8.63^{a} ±0.17	3.28^{a} ±0.14	2.64^{a} ±0.15	0.66^{a} ±0.11	4.67^{a} ±0.09
	(4-6)	4.93^{a} ±0.15	8.73^{a} ±0 25	3.35^{a} ±0.14	2.69^{a} ±0.13	0.68^{a} ±0.11	4.47^{a} ±0.14
Overall all means		4.09^{a} ±0.24	8.53^{a} ±0.27	3.32 ^{a} ±0.13	2.66^{a} ±0.22	0.67 ^{a} ±0.21	4.53^{a} ±0.24

Mean data ± Standard deviation. ^{a,b}Means different superscript letters in a column are significantly different ($p < 0.05$). SNF: Solids not fat

4. Discussion

In the present study, Nubian goat kids were born with a mean birth weight of 2.80 ± 0.18 kg. The Nubian goats have average kidding intervals of 7 months, birth weights were in the range of 2.5-3.0 kg, the males weigh 22.2 kg and females revealed 18.0 kg at 12 months[21]. The Sudanese Nubian kid's birth weight was 2.344 ± 0.557 kg[22]. Additionally, Baladi kids were reported with the lowest overall mean birth weights (2.47 vs. 2.43 kg) for female and male goats in Eygpt[23].

The obtained means birth weight of kids in the present study revealed 3.72 ± 0.54, 3.73 ± 0.55, and 3.35 ± 0.52 kg for Damascus, Mazain, and Alpine goats, respectively. The obtained values were lower in comparison with those reported for the Nubian goats. Accordingly, the sex of the kid, type of birth, and year/season of kidding had a significant effect on birth weight, while the parity order and nutritional supplementation had no significant influence on birth weight[22].

The average birth weights of male and female Damascus goat kids raised in Sudan were found to be 3.63 ± 0.03 kg and 3.47 ± 0.024 kg, respectively, which aligns with the current findings. However, overall mean birth weights reported for female and male kids of Shami goats (2.81 vs. 2.47 Kg) raised in Eygpt were lower compared to the obtained values in the present study[23]. In addition, a lower average body weight for Alpine kids at birth (2.73 kg) was reported in Serbia[15]. Similar to the present study, the birth weight of Damascus goats was significantly higher than that of Alpine-Damascus crossbred kids[25]. However, a higher overall mean (4.18 ± 0.014 kg) was reported for the birth weight of Damascus kids in the intensive production system in Syria. The birth weight revealed average means of 4.21 ± 0.031 kg for the male and 4.15 ± 0.032 kg for the female kids[14]. During the suckling periods, the daily weight gains of male kids were superior compared with those of females[10]. The obtained variation could be due to the management conditions, such as shortage of forage and lack of concentrates, high disease pressure, and low veterinary care, which did not allow the animals to express their full genetic potential[26]. In addition, the weight at birth is influenced by maternal nutrition, the genetic traits of the mother, and the size of the litter, which is likewise affected by the mother's genetic characteristics[27]. The male kids exhibited significantly greater birth weights compared to their female counterparts, while the birth weights of kids resulting from single births were marginally higher than those from multiple births[28]. Moreover, the daily weight gains of triplets were significantly lower than single-born kids and twins during all suckling phases, and the daily weight gains increased steadily with an increased birth weight[10]. The increased birth weight observed in single-born kids can be attributed to the greater availability of nutrition and the additional space within the mother's uterus during the prenatal period, in contrast to that of multiple births[14]. Additionally, there is no competition between kids during the postnatal period for the milk[11,14].

The does involved in the current study were of varying parities, specifically second, third, fourth, and fifth, and exhibited different body weights, Nubian goats averaged 50.5 ± 1.21 kg at the Animal Research Center farm, while Damascus, Mazain, and Alpine goats from Al-nawader farm had average weights of 60.5 ± 1.55 kg, 63.0 ± 1.15 kg, and 55.3 ± 1.35 kg, respectively. Similarly, the mean body weights of adult Boer crossbreds were 4.74 kg higher compared to those of indigenous goats[26]. Previously the average age and body weight of Damascus doe at first kidding revealed 16.5 months and 56 kg[24], while the average body weight of the Egyptian Nubian and Alpine goats (Zaraibi) was 25-50 kg[10] and 54.96 kg[15], respectively. According to the obtained data in the present study, the body weight of does of the different breeds correlated with the body birth weight of the kids. However, it is in line with a previous study that found the kids delivered at first parity had lighter weaning weights (12.84 kg) in comparison to other parities[14]. It could be due to the advanced physiological processes associated with increased parity, particularly the udder functions of the dam, which result in greater milk production for the suckling kids[14].

The average age at which Nubian goats first give birth was 13.5 ± 0.29 months, while the exotic goat breeds (Damascus, Mazain, and Alpine) in Khartoum State gave

their first kidding at an earlier age (Table 2). However, higher body weight (16.79 ± 0.59 kg) was reported for Nubian does in Sudan[29]. Furthermore, the Damascus crosses had the advantage of heavier weights, better body conformation, and higher milk production[30].

The present study indicated that the Nubian goat breed produced a higher milk yield of 249 kg and had a shorter lactation period of 150 days, in contrast to the findings for Sudanese Nubian goats, which showed an average yield of 89.18 ± 38.60 kg and a lactation length of 181.12 ± 51.36 days[31]. Moreover, the number of kids suckled affected only the milk yield[31]. The milk yield of Zaraibi does range from 96 to 208 kg[30]. Milk yield was affected by month of kidding, parity number, and litter size in all phases of lactation in Saanen goat[32]. The average kidding interval for the Sudanese Nubian goats was reported as 278.05 ± 75.19 days[31]. Additionally, some does of Damascus goats in Sudan were dried before completing the 305 days milk[17]. Generally, the mean lactation length was 233 ± 2.4 days for goats[32], while the lactation period for Syrian Damascus goats[14] and Alpine goats in Serbia[15] *was 199 ± 1.23 and* 220.73 days, respectively. The duration of lactation for Damascus goats reared in lowland areas with hot and arid climates during the summer season ranged from 250 to 280 days[25]. Maximum milk yield was attained in the third parity and the goats in the fourth or advanced parity showed the shortest lactation length and the lowest proportion of does reach 270 days[32]. A longer lactation period with drought seasons, poor pastures, and changes to lower-quality feedstuffs may result in energy deficiency in goats and delay the onset of estrus activity and ovulation[33].

According to Table 2, milk yield and lactation length for Damascus, Mazain, and Alpine goat breeds were significantly different in the current study. The average milk production was 519 ± 0.3 kg for goats[32], whereas, higher estimates for total milk yield (413 ± 5.98 kg) and daily milk yield (2.1 ± 0.02 kg) were obtained for the Syrian Damascus goats[14]. Although the Alpine goat showed a total milk yield of 531.66 kg in Serbia[15] the highest milk yield for 305 days of lactation was found in goats of the Saanen breed (630.14 ± 43.64 kg). It significantly exceeded the milk yield of Nubian (608.70 ± 83,64 kg) and Alpine (554.17 ± 30.86 kg) goats in Russia and their average daily milk yield revealed 2.15 ± 0.13, 1.84 ± 0.20, and 1.76 ± 0.09 kg, respectively[34]. The results of current study indicated that Egyptian Nubian goats yield between 150 and 300 kg of milk during each lactation period[10]. Meanwhile, the lactation milk production of Damascus goats, which are kept in lowland areas with hot and arid climates during the summer season, ranged from 300 to 600 liters [25].

Similarly, Mahmoud et al.[17] reported that the milk yield for Damascus goats at first kidding was significantly higher in the early lactation stage (1.34 ± 0.02 L). Then it decreased gradually until the end of lactation (0.96 ± 0.02 L). The Nguni goats yielded a greater quantity of milk during the early, mid, and late stages of lactation compared to both Boer and non-descript goats[35]. On the other hand, the overall milk yield was found to increase from 254.3 kg for 2-year-old to 297.3 kg for 5-year-old does[13]. Furthermore, the peak milk yield of Syrian Damascus goats increased significantly from the first parity (3.01 kg) to the third parity ($p < 0.05$, 3.67 kg). It could be due to the increase in feed utilization, udder capacity, and the development of the epithelial cells with increasing parity. However, a reduction in the number of secretory cells with increasing age could decline in peak milk yield after the third parity[14]. Additionally, *t*he maximum milk production of Saanen goat was attained in third parity, and goats delivering multiple kids had slightly superior milk yield in detriment of milk fat and protein[32].

The average litter size of Nubian goats in the present study was 1.70 ± 0.61. A lower average litter size (1.12 ± 0.36) was reported previously for Sudanese Nubian goats[31]. However, a high value was reported for the average litter size of Nubian goat breeds (2.0)[36]. Moreover, the Egyptian Nubian goat's rate of producing twins is approximately 2.5[10]. Goats frequently deliver twins or triplets instead of a single kid, although this can vary based on the breed[37]. The older does (> 2.69 years) with a history of larger previous litter size (> 1.65), higher parity (> 2.31) and more body weight (> 20.5 kg) are associated with an increased likelihood of multiple litter size[36]. The litter size and kid birth weight are found to affect the daily weight gains during the pre-weaning period, as single-born kids had higher daily weight gains on average compared to the multiple-born kids[10].

The average litter size of goat breeds in the present study was not significantly different. It has been observed that mammary development during gestation is influenced by the number of offspring, which in turn impacts milk production, irrespective of factors, such as age, body weight, and seasonal variations[38]. It was reported that the overall average litter size in goats was 1.4 while births occurred throughout the year[29]. Damascus goats may be better than the Kilis goats breed in Turkey as the litter size, lactation milk yield, and lactation period of the Damascus goats were significantly higher than those of the Kilis goats[28].

The chemical composition of goat milk samples obtained from Nubian goat breeds and exotic (Damascus, Mazain, and Alpine) goat breeds in Khartoum State revealed significantly different means of some milk constituents ($p < 0.05$, Table 3). In the present study, the composition of goat milk samples obtained from Nubian goats showed the protein, fat, and lactose content of milk as 3.58 ± 0.08%, 4.82 ± 0.24 %, and 4.78 ± 0.09%, respectively (Table 3). The values were greater than those previously documented for the milk of the Nubian goat, which was 3.26 ± 0.30% for protein, 3.53 ± 0.27% for fat, and 4.44 ± 0.32% for lactose content[39]. The obtained results were in line with previous studies, which found that the goat milk was influenced by breed[32,34,40-43].

Table 3 demonstrates that the fat content of milk was higher in Nubian followed by Damascus and Mazain goats while lower levels were found in the Alpine goat breed. Similarly, the fat in the milk of goats of the Nubian breed was significantly higher (4.30%) compared to those of Alpine (4.22 ± 0.07) and Saanen (4.02%) goats[34] ($p < 005$).

The most variable component of goat milk is the fat content[44]. Milk fat concentration may be influenced by the lipid content in the diet, the level of fat supplementation, and the quality of ingested fat[45].

The higher value of protein was found in the milk of the Mazain goat breed (3.62 ± 0.09%) and the lowest was reported for Alpine (3.33 ± 0.07) as shown in (Table 3). However, the highest protein milk content belonged to the Alpine breed (3.72%) compared to that of Saanen (3.55%) and Nubian (3.61%) goats[34].

The current study showed significant differences among the breeds in the average milk lactose content, where Mazain followed by the Nubian and Damascus goat milk contained more lactose in comparison to the Alpine ($p < 0.05$) (Table 3). Lower fat (2.91%), but higher solids non-fat (9.48%), protein (3.59%), and lactose (5.04%) were reported for the milk of Boer goats[35]. The obtained results agreed with some of those previously reported higher values of milk total solids, fat, and protein content for Nubian goat, and lower values of milk total solids, fat, and protein content for Alpine goat[43]. Moreover, the protein, fat, and ash content in Alpine goat milk revealed 4.53 g/100 g, 4.65 g/100 g, and 0.94 g/100 g, respectively. These values were higher compared to the Saanen goat milk which revealed protein 3.64 g/100 g, fat 3.20 g/100 g, and ash content 0.88 g/100 g[44]. Conversely, lower means of milk fat, protein, and lactose were reported[46] for Alpine goat breeds as 3.10%, 3.43%, and 4.17%, respectively. In Croatia and Slovenia, means of milk fat was reported as 3.11%, protein 3.34%, and lactose 4.36%. In Serbia, the milk fat content of the Alpine goat was reported 3.33% and the milk protein content was 3.16%[15]. In addition, higher values were reported in the milk of Saanen goat as the total solids were 12.1 ± 1.02%, fat content was 3.6 ± 0.54%, the protein was 3.1 ± 0.39%, lactose was 4.8 ± 0.13%, and ash was 0.61 ± 0.23%[32]. The variation in milk composition observed among various goat breeds can be attributed to multiple factors, including genetics[41,47,48], nutrition[48-51], parity, stage of lactation[17,35,52], milking frequency[53], environmental conditions[41,48], as well as other physiological status[54]. The goats delivering single kids had a significantly higher content of milk fat ($p < 0.05$) (4.29 vs. 4.15%) and a significantly higher content of milk protein ($p < 0.01$) (2.95 vs. 2.87%) in the milk of Saanen goat[32]. Moreover, the milk solids non-fat, fat, and protein were negatively correlated with the increase in milk yield[55]. The decline in the percent of total milk solids of Saanen goats during summer may indicate a correlation with the rise in milk yield associated with extended daylight hours[32].

The average SNF content of goat's milk reported in the current study showed significant differences in the progress of lactation in some parities for goat breeds as shown in Tables 4, 5, 6, and 7 ($p < 0.05$). Similarly, the SNF content was higher during the early stage of lactation and then decreased during the mid-lactation, before were increased gradually during the late stage of lactation[17]. The increase in the concentration of protein and fat in subsequent stages of lactation had a direct effect on the content of total solids and SNF[56]. The total solids content within various species and breeds significantly impacts milk composition, irrespective of which species or breed exerts the most considerable influence on milk characteristics[38].

The results of the current study indicated that the composition of goat milk was influenced by the lactation process. The means of fat and protein percentages varied among the three groups of lactation. The data in Tables 4, 5, 6, and 7 indicate higher values of fat and protein during the 5th and 6th months of lactation compared to earlier months of lactation for some parities of the studied goat breeds. The milk of Damascus goats showed higher total, SNF, and protein (13.49 ± 0.084%, 9.11 ± 0.049%, and 3.59 ± 0.03%), respectively during the first 2 months of lactation compared to the values reported during the 3rd and 4th months of lactation as 12.25 ± 0.08% solids, 8.40 ± 0.03% SNF, and 3.27 ± 0.02% protein[17].

The lowest values of milk fat (3.00%) and protein (3.22%) were observed at the beginning of lactation in the Alpine goat breed (Table 7), whereas for the Nubian goat breed (Table 4), the highest values were found at the 5th and 6th months of lactation (5.94% and 3.79%, respectively). The findings are in line with Zamuner et al. (2020), who found the lactation period significantly affected the milk composition, whereas in late-lactation higher fat and protein content was observed in comparison to mid-lactation. The rise in milk production may be the contributing factor[55].

It is concluded that the protein content of milk during lactation was not significantly different in some parities ($p > 0.05$, Table 3). The parity number did not affect the percentages of milk fat or protein content in goat milk[32]. Although variations of crude protein of milk might be due to variations of the stage of lactation as was reported previously[17,57], in Polish White improved goats, the protein content of milk increased with the progress of lactation[56]. There was a stable increase in protein percentage in the early and late lactations of goats[35,52]. There was an increase in fat and protein content in goat milk during the early and late lactation periods[58].

The obtained results agreed with those which found the lowest values of fat (3.46%) and protein (2.86%) at the peak of lactation, whereas the highest values were found at the end of lactation (4.53% and 3.34%, respectively)[40]. Variation in the composition and ultimately density could be attributed to various factors, such as the stage of lactation, climatic conditions, including microclimatic pattern, the feeding pattern during the period of study, housing conditions in fall and winter, genetic group, and temperature[48].

In the present study, the casein and whey protein content of milk followed the same pattern of protein, whereby higher values of casein and whey proteins during 5th and 6th months of lactation were found (Tables 4, 5, 6, and 7). In Sudan, the milk of Damascus revealed 2.87 ± 0.025% vs. 2.60 ± 0.014% casein, 0.72 ± 0.007% vs. 0.65 ± 0.004% whey proteins, 0.19 ± 0.01% vs. 0.15 ± 0.003 mg/1000g albumin and 0.27 ± 0.003 vs. 0.24 ± 0.001 mg/1000g β-lactoglobulin during the early and mid-

lactation stage, respectively[17]. On the other hand, the Saanen breed contains on average 3.55% of total protein, 2.77% of casein, and 0.78% of whey protein[34]. Additionally, the levels of milk fat and casein increased following parturition, subsequently declining thereafter[59]. The reasons attributed to the dilution effect due to an increase in milk volume until lactation peaks, and a decrease in fat and protein content mobilization that decreases the availability of plasma non-esterified fatty acids and energy balance[59].

The lactose content showed higher values during the first 2 months of lactation in the milk obtained from some parities (second and fourth parities in Nubian, third and fourth parities in Damascus, second and fourth parities in Mazain, and third in Alpine) goat breeds, and maintained constant levels till the 6th months of lactation with non-significant variation ($p > 0.05$). This is, in agreement with the findings of Chilliard et al.[58], who reported that the lactose content in milk increased at early and late lactation.

4. Conclusion

The findings of the current study indicated that the production and reproduction performance of dairy goats in Khartoum State, Sudan, differs between local and imported breeds. The SNF content of milk showed higher values in Damascus breeds, followed by Mazain and the Nubian goat breeds showed the highest fat percentage in milk and the Alpine goat showed the lowest one. The protein content of milk showed higher values in Mazain goat and lower values in Alpine goat. The chemical composition of milk indicated some significant variations during the progress of lactation, while it showed no significant difference for all parities in all goat breeds. Further research should be conducted concerning the whole period of lactation in different goat breeds in Sudan.

Declarations

Competing interests

The authors declare there are no competing interests regarding this study.

Authors' contributions

Nadia M. A. Mahmoud collected samples, processed the data, analyzed and interpreted the data generated. Ibtisam E. M. El Zubeir, designed and supervised the research and finalized the manuscript. The authors revised and approved the final edition of the manuscript.

Authors' relationships and activities

Authors are responsible for disclosing all relationships and activities that might bias or be seen to bias their work.

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Availability of data and materials

Data from the current study will be available upon reasonable request.

Ethical considerations

The authors declare that this manuscript is original and is not being considered elsewhere for publication. The authors have checked all ethical issues.

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