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Research Article

Husbandry, Production, and Milk Composition of Sheep in Khartoum State, Sudan

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ABSTRACT

Introduction: In Sudan, sheep are predominantly raised under nomadic production systems for live animals and meat export, whereas their potential for milk production remains largely overlooked. This study aimed to characterize the production performance and milk composition of sheep in Khartoum State, Sudan.

Materials and methods: A cross-sectional design was employed, utilizing closed-ended questionnaires and direct interviews with 20 sheep owners to document husbandry practices and ewe production performance. Additionally, colostrum (n=20) and milk (n=80) samples collected from 20 ewes were analyzed for solids-not-fat (SNF), fat, protein, lactose, and density.

Results: The Shugor sheep breed was predominant (95%) among surveyed farmers, only 5% of farms-maintained production records. Sheep were primarily reared for meat (50%), meat and milk (25%), and investment/savings (20%), with only 5% dedicated solely to milk production. Water was mainly sourced from wells (70%), and ewes had *ad libitum* access (85%). Mating was occurred more in winter (60%) and autumn (35%). Natural parturition was reported in 85% of farms, with a 10% abortion rate. Produced milk was mainly used for roub (traditional product, 69.2%). Summer was the preferred season for milk production and sales (81.8%). Colostrum from Shugor ewes showed significantly higher mean SNF (15.28 ± 1.30%), protein (6.17 ± 0.50%), and lactose (8.03 ± 0.72%) compared to normal milk (10.68 ± 0.43%, 4.22 ± 0.17%, and 5.55 ± 0.22%, respectively). No significant difference was observed in fat content between colostrum (6.11 ± 0.43%) and normal milk (6.72 ± 0.62%).

Conclusion: The Shugor breed was the most common sheep type in the study area, raised primarily for meat production. Sheep milk is rich in total solids, fat, and protein.

1. Introduction

In many developing countries, both the demand and visible supply of sheep's milk are very low[1]. In Sudan, desert sheep are the main breed raised in nomadic production systems, where they provide a source of livelihood and serve as an economic asset, particularly as the country exports live animals, meat, hides, and skins to several Arab and African nations[2]. The sale of livestock significantly contributes to Sudan's gross domestic product (GDP) and provides a moderate boost to the nation's exports[3]. Sheep are among the most important animals for improving the income and well-being of rural families in Sudan, owing to their economic, social, and cultural value to rural households[4].

Traditionally, any breed of sheep can be milked but some breeds are excellent milk producers[1]. Sheep milk is highly nutritious food as it has high concentrations of total solids, fat, protein and minerals compared to other domestic species[1,5,6,7]. Furthermore, the compositional profile of sheep milk closely resembles that of human milk, alongside its therapeutic properties such as antiviral, antibacterial, anti-inflammatory, and immune-modulatory effects[5].

In Sudan, sheep milk contained 6.59% fat, 4.11% protein, 10.05% solids not fat (SNF), 5.28% lactose and 0.21% acidity[8]. However, higher values were reported for the total solids (16.42 ± 0.29%) and fat (4.66 ± 0.47%) content and

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lower SNF (11.57 ± 2.43%) and protein (4.64 ± 0.99%) content, while similar lactose (5.28%) content were reported[9]. The present study aimed to characterize the rearing practices of sheep under a semi-extensive production system, as well as to evaluate their milk for compositional parameters (SNF, fat, protein, lactose, and density) and acidity.

2. Materials and methods

2.1. Ethical approval

This study is conducted according to the institutional animal care as stated by ethical committee guidelines of Khartoum University, Sudan. Moreover, it was approved by the research board of the Faculty of Animal Production, University of Khartoum during its meeting at 2017.

2.2. Location

The study was conducted and data analysis was done at Dairy Chemistry Laboratory, Faculty of Animal Production, University of Khartoum, Sudan.

2.3. Study area and sheep rearing

Khartoum State, is located in central Sudan and it lays in the semi-arid zone between the latitude 15.08-16.39°N and longitude 31.36-34.25°E.

The present study was conducted from June to September by investigating a total of 20 farms rearing sheep in Eastern Nile Province (AlShegla Complex), Khartoum North, Khartoum State. Moreover, colostrium and milk of 20 lactating ewes (Shugor) from 5 dairy farms were tested in the present study for their compositional content. The rearing system in the selected farms are semi-extensive and the main purpose of keeping those ewes is for subsistence of dairy workers. The numbers of ewes are in a range between 20 and 150 head of sheep that include ewes, rams and lambs. All those animals are kept in the same fence. The fodder sorghum Abu 70 (*Sorghum bicolor)* and alfa alfa hay constituted the main feed provided to the animals twice a day.

2.4. Data collection

A questionnaire comprising close-ended questions was designed for data collection. The sample size (n=20 ewe owners) was determined based on the feasibility of accessing semi-extensive sheep farms in Khartoum State, with inclusion criteria requiring owners to have at least three lactating ewes and to practice semi-extensive management for a minimum of two years. Owners were selected purposively from farms meeting these criteria. Direct interviews and group discussions were subsequently conducted with the 20 selected owners to gather information on general management, breeding practices, and milk utilization.

2.5. Collection of milk

The colostrum (n= 20) and milk samples (n= 80) were collected randomly from 20 females' sheep on the farms using hand milking. Bulk milk and colostrum samples (40 ml) were collected using dry clean bottles. The samples were labeled and transferred into an icebox (4-5ºC) to the laboratory of Dairy Chemistry, Department of Dairy Production, Faculty of Animal Production, University of Khartoum, Sudan for chemical analysis.

2.6. Chemical analysis of ewes' milk

The major constituents (SNF, fat, protein, lactose and density) of the ewes' colostrum and milk samples were determined first day, 7, 30, 60 and the 90 days after parturition using the milk analyzer Lactoscan 90 according to the manufacturer instructions (Milkotronic LTD, Nova Zagora, Bulgaria). The details of the procedure were reported in the technical manual.

2.7. Statistical analysis

The general information about the rearing and production of the ewes were analyzed using Statistical Package for Social Science (SPSS) version 16 and descriptive statistics procedures were obtained[10]. Meanwhile, the milk constituents were analyzed using the General Liner Model procedure in SPSS version 16[10]. Differences between means were calculated using ANOVA test following Duncan's Multiple Range Test for finding significant differences ($p < 0.05$).

3. Results

3.1. Sheep rearing

As shown in Table 1, among the sheep farms located in Al Shegla (Eastern Nile locality, Khartoum State), the primary purpose of keeping ewes is meat production (50%), followed by combined meat and milk production (25%), saving money (20%), and exclusively milk production (5%). The predominant breed is Shugor (also known as Ashgar, Figure 1), representing 95% of the sheep population in the surveyed farms. However, record-keeping practices are poor, with only 5% of farms maintaining production records (Table 1). All respondents confirmed that the open production system, relying on natural grazing pastures, is the primary husbandry system practiced in Eastern Nile Locality (Table 1). In 95% of the investigated farms, no supplementary feeding is provided to the ewes (Table 1). The main sources of drinking water for the sheep herds are wells (70%), public pipes (15%), and rainwater (10%). Furthermore, water is provided *ad libitum* in 85% of the farms (Table 1).

The breeding or service season for ewes occurs mainly in winter (60%), followed by autumn (35%), and summer (5%) as presented in Table 1. The effect of breeding season was statistically significant ($p < 0.05$). Natural parturition was reported in 85% of Shugor ewes, while only 15% required assistance during delivery. Meanwhile, abortion cases accounted for 10% of the study herd (Table 1).

Figure 1. A typical Shugor male sheep with its characteristic brown colour (Source: Animal Production Research Center/ Kuku)

Table 1. The husbandry of ewes in *Eastern* Nile, Khartoum State, Sudan

Parameter	Total number of respondents	Percentage
Purpose of breeding		
Meat production	10	50
Dual purpose	5	25
Saving money	4	20
Milk production	1	5
Breeds		
Shugar	19	95
Watish	1	5
Records		
Keeping records	1	5
No records	19	95
Production systems		
Closed farms	5	95
Back yard	1	5
Sources of water		
Wells	14	70
Pipes	3	15
Rain	2	10
Other	1	5
Frequency of drinking water		
Ad libitum	17	85
Once a day	2	10
Other	1	5
Offering supplementary ration		
Yes	1	5
No	19	95
Service season		
Winter	12	60
Autum	7	35
Summer	1	5
Parturition		
Natural	17	85
Via help	3	15
Cases of abortion		
Yes	2	10
No	18	90

3.2. Milk production performance

The milking frequency is either once a day (85%) or twice a day (15%) as shown in Table 2. The average produced milk is used mainly for processing (69.2%), self-consumption (23.1%) and sale (7.7%) as shown in Table 2. Traditional

product (roub) is the only product processed from ewes' milk. The preferable season of production and selling of milk was stated by the respondents as during summer (81.8%) compared to winter season (18.2%). Marketing and sale of milk revealed 58.4%, while only 4.2% was estimated for selling the products. Meanwhile, 37.5% was provided for rearing lambs (Table 2). Moreover, the lambs are given the milk mostly during the day (62.5%) and in the morning (31.25%) compared to the evening (6.25%).

Table 2. The production performance of ewes kept in *Eastern* Nile, Khartoum State, Sudan

Parameters	Total number of respondents	Percentage
Milking time		
Once a day	12	85.7
Twice a day	2	14.3
Uses of milk		
Processing	9	69.2
Self-consumption	3	23.1
Sale	1	7.7
Milk marketing		
Sale of milk	14	58.3
Feeding lambs	9	37.5
Sale of products (Roub)	1	4.2
Preferable season of milk production and selling		
Autum	9	81.8
Winter	2	18.2
Time of offering milk to the lambs		
Morning	5	31.25
Evening	1	6.25
During the day	10	62.5

3.3. Composition of colostrum and milk

As presented in Table 3, the mean SNF content of colostrum from Shugor ewes (15.28 ± 1.30%) was significantly higher compared to milk samples collected at 7 days (10.68 ± 0.43%), 30 days (10.17 ± 0.17%), 60 days (9.53 ± 0.31%), and 90 days (9.39 ± 0.20%) of lactation ($p < 0.05$).

Regarding fat content, colostrum contained 6.11 ± 0.43%. At 7 days postpartum, milk fat was 6.72 ± 0.62%, followed by 6.57 ± 0.38%, 6.86 ± 0.49%, and 6.25 ± 0.48% during the first, second, and third months of lactation, respectively (Table 3).

Protein content also showed highly significant differences ($p < 0.05$) between colostrum (6.17 ± 0.50%) and milk obtained at 7 days (4.22 ± 0.17%), 30 days (4.02 ± 0.06%), 60 days (3.77 ± 0.13%), and 90 days (3.68 ± 0.08%) of lactation (Table 3).

Lactose content was significantly higher in colostrum (8.03 ± 0.72%) compared to normal milk at 7 days (5.55 ± 0.22%), 30 days (5.57 ± 0.13%), 60 days (5.00 ± 0.16%), and 90 days (4.98 ± 0.10%) of lactation (Table 3). Finally, milk density was significantly higher ($p < 0.001$) in colostrum (1.05 ± 0.00 g/cm³) than in normal milk (1.03 ± 0.00 g/cm³), as shown in Table 3.

Table 3. Comparison of colostrum and milk of ewes reared in Khartoum State, Sudan

Measurements	Solids not fat (%)	Fat (%)	Protein (%)	Lactose (%)	Density (g/cm³)
Colostrum	15.28 ± 1.30^{a}	6.11 ± 0.43^{a}	6.17 ± 0.50^{a}	8.03 ± 0.72^{a}	1.05 ± 0.00^{a}
Milk (7 days)	10.68 ± 0.43^{b}	6.72 ± 0.62^{a}	4.22 ± 0.17^{b}	5.55 ± 0.22^{b}	1.03 ± 0.00^{b}
Milk (30 days)	10.17 ± 0.17^{b}	6.57 ± 0.38^{a}	4.02 ± 0.06^{b}	5.57 ± 0.13^{b}	1.03 ± 0.00^{b}
Milk (60 days)	9.53 ± 0.31^{b}	6.86 ± 0.49^{a}	3.77 ± 0.13^{b}	5.00 ± 0.16^{b}	1.03 ± 0.00^{b}
Milk (90 days)	9.39 ± 0.20^{b}	6.25 ± 0.48^{a}	3.68 ± 0.08^{b}	4.98 ± 0.10^{b}	1.03 ± 0.00^{b}
Significant level	0.05	0.143^{ns}	0.05	0.05	0.05

^{a,b} Superscript letters within the same column show significant difference ($p < 0.05$), ns: Not significant

4. Discussion

Similar to the present study, 40% of dairy owners in Khartoum State are keeping other animal beside their dairy cows including sheep[11]. The present result supported the previous study stating that sheep keeping in Sudan is mainly for meat production[3]. Sheep is one of the first domesticated animals by humans and the main reasons for its raising include the production of meat, milk and dairy products, fleece and skin[12].

Shugor sheep ecotype is a moderately large sheep with colour that range from light to dark brown and this sheep is found mainly in the natural pastures of Butana plains as well as the irrigated agricultural schemes of Gezira scheme[13]. Moreover, Ashgar and Dubasi in Gezira State are 2 of the important sheep breed in the country[2].

Record-keeping practices among sheep owners are generally poor, with only 5.9% maintaining production records[4]. In contrast, approximately 25% of the surveyed dairy farms in Khartoum North were found to keep records[11].

The open production system is considered suitable for rearing Sudan desert sheep, as it represents the most cost-effective feeding system[14]. Livestock producers in Sudan are primarily pastoralists, agro-pastoralists, or sedentary farmers[14]. Nevertheless, the adoption and promotion of an improved sedentary system for sheep rearing should be encouraged, particularly around irrigated agricultural areas, to enhance both farmer income and animal welfare[15].

Supplementation has been shown to improve sheep productivity[16,17], increase the sale revenues of lambs[17], and

enhance the milk composition of ewes[18]. Furthermore, supplementation positively affects the fat properties in milk, cheese, and meat products[19]. Regarding water availability, it is important to consider potential shortages of both feed and water for sheep flocks, especially during the dry season[4].

Seasonal reproduction in desert sheep is closely linked to feed availability during the rainy season[16]. However, most ewes are reported to lamb throughout the year[4]. Sudanese sheep are noted for their productivity, achieving more than one parturition per year[20].

A moderate diet supplementation regimen, applied every three days, has been shown to be an effective strategy for reducing nutritional stress in Sudanese desert ewes and enhancing their reproductive performance by lowering the abortion rate[16]. Furthermore, the differences observed between sheep at the El Huda station and those reared under the traditional system in South Darfur are primarily attributed to controlled breeding programs, which result in poor reproductive performance and high mortality rates[20]. The survival rate for Shugor lambs was estimated at 84.72%[16]. Similarly, an abortion rate of 17.73% has been reported for sheep flocks in Ethiopia[21]. Therefore, proper management practices including adequate housing, appropriate general hygiene measures, and accurate feeding and watering of sheep flocks are expected to reduce the incidence of abortion[21].

Regarding milking practices, twice-daily milking is commonly used for dairy sheep flocks raised in New Zealand[22]. Increasing milking frequency from two to three times per day has been reported to raise milk yield by 3–36%. Conversely, reducing the frequency from twice to once daily decreases milk yield by 9–67%[23]. Most of the produced milk is used for subsistence of the workers. Moreover, keeping sheep herds in dairy farms dealing with cattle is for subsistence of dairy workers. Sheep milk can be a suitable alternative to breast milk and infant formula[24]. Sheep milk is suitable for processing yoghurt because of its high content of total solids and protein[25,26]. Also, the higher fat content of sheep milk can be utilized in new production line, that can produce sheep milk cream as a secondary product of yoghurt production[25]. Sheep milk is more popular among consumers in form of cultured dairy products such as cheese and yoghurt[1]. Moreover, sheep's milk could be possibly enriched camel's milk at a rate of 50-75% to produce camel milk cheese with good characteristics[9].

Selling of milk and products was practiced in the study area. Sheep milk is rich for processing of some dairy products[7,8]. Yoghurt made from sheep milk revealed more acceptability for the texture and the flavor score[7,25]. Furthermore, differences exist in the chemical composition of yogurt made from camel milk compared to camel–sheep milk mixtures[27]. Fermented sheep milk offers beneficial properties for human health[28], including antioxidant, antibacterial, and antihypertensive effects as a functional food[29]. The physicochemical characteristics and nutritional value of sheep milk provide advantages in manufacturing products containing prebiotic and/or probiotic bacteria, which is important for the functional food market[6]. The use of sheep milk is also significant for enriching yogurt made from other species' milk due to its high content of total solids, fat, and protein[30]. Moreover, the addition of sheep milk to camel milk improves the quality and acceptability of camel milk yogurt[31,32].

The present study examined the effect of lactation stage on milk composition of Shugor ewes by comparing colostrum with milk obtained over three months of lactation. The average lactation period for dairy sheep ranges from 180 to 240 days, whereas non-dairy breeds have a lactation period of 90–120 days[1].

The average SNF content of raw sheep milk has been reported as 10.05 ± 0.04%[8]. Sheep milk possesses superior nutritional content compared to cow and goat milk, with higher levels of fat (7.1%), protein (5.4%), and minerals (0.9%)[1]. In Awassi sheep, values of 6.27 ± 0.10% fat, 5.12 ± 0.05% protein, and 4.81 ± 0.05% lactose have been reported[33].

Fluctuations in fat content may be attributed to variations in the feed available to ewes, particularly concentrate feed. A fat content of 6.59 ± 0.02% has been previously reported in sheep milk[8], and sheep milk generally has significantly higher fat content compared to cow and goat milk[29]. It has been shown that providing high-nutrient supplemental feed alongside grazing can increase protein, SNF, and butterfat content[17]. Additionally, sheep milk contains more healthy fatty acids, which improve digestibility and promote cardiometabolic health[34]. The previously reported value for the protein content for sheep milk was 4.11±0.07%[8]. Some authors reported that the protein content for sheep milk was high[1,25]. The allergic reactions to cow's milk can be avoided by the people and infants by consuming sheep's milk and its derived dairy products[12]. Moreover, sheep milk has a significantly higher content of protein and its consumption also helps in avoiding the cow milk sensitivity; since sheep milk's casein profile is different[29]. In addition, sheep milk is less likely to cause allergies, as it has lower amount of α_{s1}-casein (25-30%), as the levels of α-lactalbumin and β-lactoglobulin known to cause allergy[35]. Furthermore, because of its smaller fat globules, greater medium-chain fatty acids and lower contents of alpha-s1-casein, the sheep milk can be tolerated by some people showing intolerant to the proteins of cow's milk much better[29]. Generally, sheep milk has better nutritional profile than cow or goat milk, usually having higher level of fat, protein and minerals[1]. Moreover, the most important of sheep milk is its high content of some bioactive compounds that include lactoferrin, lysozyme, casein-derived peptides, immunoglobulins and oligosaccharides that of known anti-inflammatory and antibacterial properties[36].

The mean value found for lactose content goes in line to those reported for raw sheep milk (5.28%)[8,9]. Similarly, 1.0417±1.44 g/cm^3 was estimated for the density of ewe's milk[9]. Similarly, 1.0417±1.44 g/cm^3 was estimated for the density of ewe's milk[9].

Lactose in sheep milk as other ruminants is lower at the beginning of lactation in the colostrum stage and that colostrum contains more fat, protein, ash, vitamins, minerals and hormones[37]. In addition to its nutritive values colostrum encompasses a vibrant combination of proteins that dynamically take part in the neonate's defence against infections and other postpartum environmental hazards[38]. Moreover, the cytokines content of colostrum has a vital preventive and protective health benefits roles including antimicrobial, antioxidant, anti-carcinogenic, anti-stress, anti-allergic, cholesterol-lowering and lactose intolerance[37]. Also,

sheep milk is known as an important source of bioactive substances for people requiring special diet as the low level of lactose levels together with the high medium-chain fatty acids were reported to improve the digestibility[29].

The reported variations of milk composition in the present study compared to other published study might be due to the differences of breed, stage of lactation, feeding and nutrition as well as environmental factors[29]. Moreover, milk yield, chemical composition, quality characteristics and nutritional value are found to influence by both feeding and rearing systems of animals in addition to other factors including breed, age, and season[18].

5. Conclusion

This study concluded that several dairy farms in Khartoum State keep sheep alongside cattle, with the Shugor ecotype being the predominant breed. The primary purpose of rearing sheep is for meat production or combined meat and milk production. Notably, sheep colostrum exhibited a significantly richer composition compared to normal milk. Therefore, this study recommends establishing sheep farming enterprises by selecting breeds with higher milk yields to produce valuable dairy products that require concentrated protein and fat content.

Declarations

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Authors' contributions

Hanan, A. Bashir choose the problem, designed the study, collected the information and milk samples, in addition to the analysis and interpretation of the data. Ibtisam, E. M. El Zubeir approved the designed experiment, supervised the study and write the manuscript.

Both authors revised and approved the final version of the manuscript.

Authors' relationships and activities

The authors confirmed that this study fulfill the criteria of the Institutional Animal Care and Use stated by Committee guidelines of University of Khartoum, Sudan. Moreover all other ethical issues including plagiarism, consent to publish, misconduct and fabricated or falsified data, dual publishing and submission, and redundancy were considered.

Availability of data and materials

Upon a reasonable Request, the data for the current study would be available.

Competing interests

The authors would like to declare that no competing interests regarding this manuscript.

Ethical considerations

The authors confirm that this manuscript is original, has not been published previously, and is not under consideration elsewhere. All sources have been properly cited, and the study is free from plagiarism or duplication. No artificial intelligence (AI) tools were used in any stage of this study or manuscript preparation.

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