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Effect of concentrate supplementation on milk yield of lactating Dromedary Camels in Red Sea State, Sudan

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Abstract

The objective of this study was to evaluate the effect of concentrate supplementation on the milk yield of grazing lactating camels. A total of sixty healthy dromedary camels, in early lactation, were randomly selected from semi-intensive farming systems across three locations: Sinkat, Sawakin, and Port Sudan (twenty camels per location). A concentrate diet containing 16% crude protein (CP) and 12.6 MJ/kg of metabolizable energy was formulated and offered to the animals in the evening. The camels were milked twice daily (morning and evening), and individual milk yields were recorded. Paired sample t-tests were used to compare milk yield before and after supplementation, and analysis of variance (ANOVA) was conducted to assess differences between locations. The results showed a highly significant increase ($P<0.0001$) in average daily milk yield, from 5.64 ± 1.53 liters before supplementation to 8.17 ± 1.61 liters after supplementation ($P < 0.001$). The mean increase in milk yield varied by location, with Sinkat showing the highest increase (2.60 ± 0.38 liters), followed by Port Sudan (2.55 ± 0.48 liters), and Sawakin (2.42 ± 0.44 liters). However, these differences between locations were not statistically significant ($P > 0.05$). In conclusion, supplementation with 2 kg of concentrate per head per day, following 7 hours of grazing, significantly increased ($P<0.05$) milk yield in lactating camels. The study recommends the use of concentrate supplementation as an effective strategy to enhance milk production in semi-intensive camel dairy systems.

Keywords: Supplementation, Milk production, Dromedary camel.

Introduction

Camels have long demonstrated a high productive potential in arid and hot climates and have traditionally served multiple roles in pastoral communities, including transport, draft work, and the production of milk, meat, hair, wool, and hides. Additionally, camels are utilized for racing and tourism in some regions (Gagaoua and Bererhi, 2022). However, the scarcity and declining quality of rangeland vegetation in

arid and semi-arid lands has forced nomadic herders to transition toward more settled and semi-intensive production systems (Konuspayeva and Faye, 2021). So camel production systems are now shifting toward the semi-intensive approach that depends mainly on feed supplements to meet nutrient requirements (Abdelrahman et al., 2022). Moreover, Faye (2013) reported that feed supplements consisting of Alfalfa hay, Rhodes grass, Barley, Wheat bran, crop by-products, and, rarely, seasonal grazing pasture are the main source of nutrients for camels, which do not cover the nutrient requirements, including trace minerals, especially during lactation. Providing additional nutrition to lactating camels during the dry season plays a key role in enhancing milk yield. In peri-urban camel production systems, targeted feed supplementation during this period can significantly improve productivity. Nutritional support can be delivered through the use of specific tree pods, such as those from acacia species, or through specially formulated feed concentrates (FAO, 2021). Nevertheless, a major constraint to milk production in lactating dromedary camels during dry periods is the limited availability and low nutritional quality of forages (Lusala et al., 2025).

Sudan hosts one of the largest camel populations in the world, estimated at 4.96 million head, ranking second globally after Somalia (AOAD, 2022).

Camel husbandry in Sudan is managed through three primary systems: the traditional nomadic system, transhumance system and semi-intensive system (Ishag and Ahmed, 2011). In recent years, a peri-urban, semi-intensive camel dairying model has emerged, particularly in Khartoum State, and has gradually expanded to other major urban centers (Shuiep and El Zubeir, 2012).

The objective of this study was to evaluate the impact of concentrate supplementation on milk production in lactating camels managed under semi-intensive, peri-urban production systems.

Materials and Methods

Study area

This study was conducted in three localities in Red Sea State during the year 2023. The Localities are Port Sudan, Sawakin and Sinkat. Red Sea State is located in the north eastern part of Sudan (latitude 17° to 22° north, longitude 33° to 38° in east). The climate of the Red Sea area is typically a semi-desert climate with high temperatures and greatly varying conditions. The average annual temperature is 30 °C in winter and about 45 °C in the summer. Generally, the area has low precipitation, less than 100 mm per year and over 90% of the annual rainfall occurs between October and January, mostly in November. The study area was characterized by the presence of various types of trees and shrubs that are browsed by the camels, such as the Arak (Salvadora persica), Heglig (Balanites aegyptiaca), Sidr (Ziziphus spinosissima), Tundob (Capparis decidua), Talih (Acacia seyal), Senamakka (Senna alexandrina), Lisan al-tayr (Ailanthus altissima), Darisa, and Tibulusmaropterus. The principal types of livestock found in the state are cattle, sheep, goats, and camels. Camels represent 6.06% of the ruminants in the Red Sea State (Anon, 2010).

Experimental animals

A total of sixty healthy dromedary camels, in early lactation, were randomly selected from semi-intensive farming systems across three locations: Sinkat, Sawakin, and Port Sudan (twenty camels per location).

Experimental feeds and feeding management

In these farms, lactating camels were allowed to graze and browse daily on available vegetation and agricultural residues in open areas surrounding the farm. Grazing typically occurred between 07:00 and 15:30 hours, for approximately 7 hours, without the calves present. After grazing, the camels were returned to the farm for milking and supplementation.

Each camel received a daily evening supplement of 2 kg of a traditional concentrate mixture. The concentrate was composed of the following ingredients: sorghum (Fatreta) 50%, wheat bran 30%, groundnut cake 17%, limestone 1.7%, common salt 1%, and a mineral mixture 0.3% (Table 1). Proximate analysis of the individual ingredients and the final concentrate mixture was conducted following AOAC (1995) standard protocols, while the metabolizable energy (ME) content was estimated according to the method described by Ellis (1980). The chemical composition of the formulated concentrate mixture was 16% crude protein (CP), 12% crude fiber (CF), and 12.6 MJ/kg metabolizable energy (Table 2). Clean drinking water was provided ad libitum to all lactating camels throughout the study period.

Milking procedure and milking frequencies

Lactating camels were hand-milked twice daily, approximately between 04:00 and 4:30 in the morning and between 3:00 and 3:30 pm. Milk let-down was typically initiated by allowing a suckling calf to stimulate the udder for a brief period (30–90 seconds). Once milk let-down was achieved, the calf was removed and manual milking commenced. Milking was performed while the camel remained standing, with the milker supporting the vessel on their knee or lap. The volume of milk produced was measured using a graduated cylinder and recorded for each milking session. Daily milk yield for each camel was calculated as the sum of the morning and afternoon yields and expressed in liters. This procedure was repeated consistently over a 30-day period.

Table 1. Concentrate mixture composition on % DM basis.

Ingredient	**%**
Sorghum	50
Wheat bran	30
Groundnut cake	17
Limestone	1.7
Salt	1.0
Vitamins and minerals mix	0.3

Table 2. Chemical composition of the concentrate mixture (on DM basis).

Items	Content
Crude protein, %	16
Crude Fat, %	3
Crude Fiber, %	12
Calcium , %	2
Phosphorus, %	1.2
Sodium, %	0.5
Chloride, %	0.7
Metabolizable energy, Mj/Kg	12.6

Statistical analysis and results presentation

The collected data were organized, edited, and statistical analysis using SPSS Statistics software (version 20.0). Descriptive statistics, including mean and standard deviations were calculated. To evaluate the effect of concentrate supplementation on milk yield, paired sample t-tests were conducted for each locality to compare milk production before and after supplementation. Additionally, analysis of variance (ANOVA) following a completely randomized design (CRD) was employed to assess mean differences in milk yield across the three localities. Statistical significance was considered at $P<0.05$ and $P<0.01$. Where applicable, mean differences were further separated using the least significant difference (LSD) test at the 5% level. Results were expressed as mean ± standard deviation (SD) and presented accordingly.

Results and Discussion

The data presented in Table 3 and Fig. 1 show effect of concentrate supplementation on average daily milk yield across the three study areas: Sinkat, Port Sudan, and Sawakin. Prior to supplementation, the data showed that the daily milk yield of experimental camels ranges from 5.13 ± 1.58 liters in Sawakin to 6.38 ± 1.07 liters in Sinkat, with an average of 5.64 ± 1.53 liters. Following supplementation, all groups showed a marked increase in milk production, with Sinkat reaching the highest post-supplementation yield of 8.98 ± 0.92 liters. Port Sudan and Sawakin also recorded significant increases to 7.99 ± 1.80 and 7.55 ± 1.68 liters, respectively.

The overall mean daily milk yield increased from 5.64 ± 1.53 to 8.17 ± 1.61 liters, representing a statistically highly significant improvement ($P<0.0001$) of 2.53 ± 0.44 liters ($P < 0.0001$). The highest mean increase was observed in Sinkat (6.38 ± 1.07 liters versus 8.98 ± 0.92 liters with a difference of 2.60 ± 0.38 liters), followed closely by Port Sudan (5.43 ± 1.64 liters versus 7.99 ± 1.80 liters with a difference of 2.55 ± 0.48 liters) and Sawakin (5.43 ± 1.64 liters versus 7.99 ± 1.80 liters with a difference of 2.42 ± 0.44 liters), all of which were also highly significant ($P < 0.0001$).

Table 4 shows the differences in milk yield before and after concentrate supplementation across the three study areas: Sinkat, Port Sudan, and Sawakin. Although the daily milk yield before supplementation varied slightly between locations (6.38 ± 1.07 liters in Sinkat, 5.43 ± 1.64 liters in Port Sudan, and 5.13 ± 1.58 liters in Sawakin) these differences were not statistically significant (P>0.05). Similarly, post-supplementation yields (8.98 ± 0.92, 7.99 ± 1.80, and 7.55 ± 1.68 liters, respectively) did not differ significantly (P>0.05) among locations.

The mean differences in milk yield after supplementation were 2.60 ± 0.38 liters in Sinkat, 2.55 ± 0.48 liters in Port Sudan, and 2.42 ± 0.44 liters in Sawakin. Despite minor numerical variations, these differences were also not statistically significant. The relative increase in milk production was approximately 40.75% in Sinkat, 47.15% in Port Sudan, and 47.17% in Sawakin.

Table 3. Effect of concentrates supplement on average milk yield (liters/day) in the study areas.

Study area	Daily milk yield/Kg		Mean differences	Sig. level
	Before supplementation	After supplementation		
Sinkat	6.38±1.07	8.98***±0.92	2.60±0.38	***
port sudan	5.43±1.64	7.99***±1.80	2.55±0.48	***
Sawakin	5.13±1.58	7.55***±1.68	2.42±0.44	***
Overall	5.64±1.53	8.17***±1.61	2.53±0.44	***

***= p< 0.0001 and Sig level = Levels of significance.

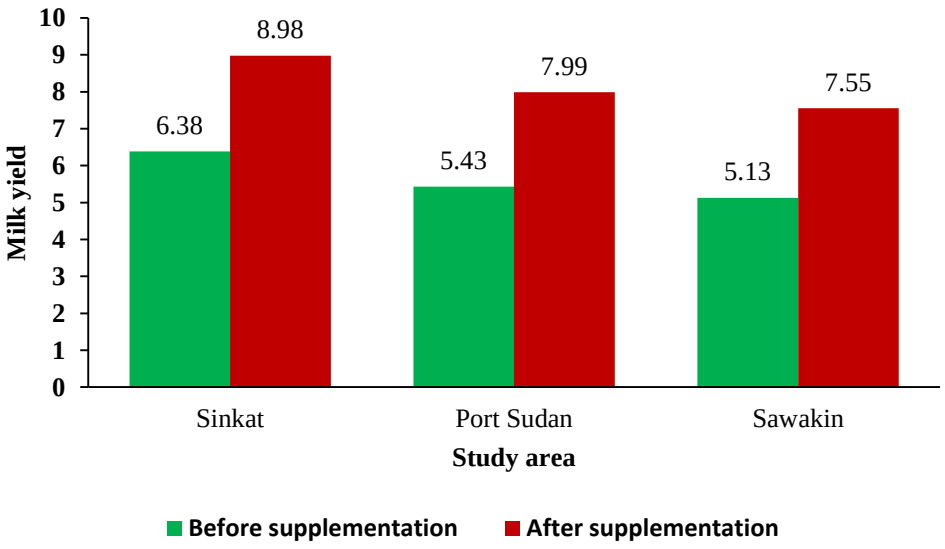

Fig. 1. Effect of concentrates supplement on average milk yield (liters/day) in the study areas.

Table 4. Effect of concentrates supplement on milk yield differences (liters/day) between the study areas.

Study area	Sinkat	Port Sudan	Sawakin	Sig. level
Daily milk yield before supplementation	6.38±1.07	5.43±1.64	5.13±1.58	NS
Daily milk yield after supplementation	8.98±0.92	7.99±1.80	7.55±1.68	NS
Mean differences	2.60±0.38	2.55±0.48	2.42±0.44	NS
Increasing percentage of milk yield	40.75%	47.15%	47.17%	NS

Sig level = Levels of significance and NS= Not significant.

The findings of this study clearly indicate that daily supplementation with 2 kg of concentrate feed significantly enhanced milk production in lactating camels, regardless of geographic location. This improvement is likely attributed to the additional energy and protein supplied by the concentrate, which helped to meet the elevated nutritional requirements of lactating animals especially under the resource-limited conditions of semi-arid environments. These results are consistent with previous research by Hasan et al. (2023) and Bakheit et al. (2008), which reported improved milk yields in camels maintained under semi-intensive systems with supplemental feeding.

The slightly greater increase in milk yield observed in Sinkat may reflect differences in baseline farm management practices, availability of natural forage, or individual animal responses. Nonetheless, the absence of statistically significant differences among the three locations suggests that the supplementation protocol was broadly effective across varying conditions.

In this study, the average increase in milk yield following supplementation was 2.60 ± 0.38 liters in Sinkat, 2.55 ± 0.48 liters in Port Sudan, and 2.42 ± 0.44 liters in Sawakin. These findings align with those of Bakheit et al. (2008), who observed significantly higher milk production in camels under semi-intensive management compared to those in traditional systems. Similarly, Hasan et al. (2023) demonstrated that supplementing lactating camels after daily grazing significantly improved milk yield across different sites in Khartoum State.

Additional support for these results is found in studies by Hassabo et al. (2012), Zayed (2012), and Suliman (2012), all of whom reported that providing extra feed to grazing camels enhanced milk output. Bhattacharya et al. (1988) also observed increased milk yield in Saudi camels supplemented with barley and lucerne forage. Furthermore, Dereje et al. (2016) found that supplementing free-ranging dromedary camels with feed in Ethiopia led to substantial improvements in both milk quantity and quality, particularly when the supplement was provided at rates of 0.5 to 0.75 kg per kilogram of milk produced.

The mechanism behind this improvement may be linked to enhanced digestibility of dry matter (DM) due to concentrate supplementation, which boosts the production of propionic acid in the rumen. Propionic acid serves as a key precursor for gluconeogenesis, leading to increased glucose availability. Since glucose is essential for

lactose synthesis (the primary osmotic regulator of milk volume) its availability directly influences milk output (Costa et al., 2009).

The average daily milk yield observed in the present study (8.17 ± 1.61 liters) closely matches the yield reported by Bakheit et al. (2016) for the Sudanese Arabi Kabaishi breed (8.36 ± 1.64 liters/day) under semi-intensive systems. It is also comparable to the 7.55 ± 1.8 liters/day reported by Faye et al. (2013) for Saudi camels fed olive cake as a supplement. However, Hasan et al. (2023) recorded a higher yield of 12 liters/day with a 90.84% increase in Khartoum, compared to the 8.27 liters/day (45.38% increase) in the current study, likely due to differences in breed or feeding strategies. In contrast, the present results surpass the 6.1 ± 0.2 kg/day reported by Faraz (2020) for Marecha camels in Pakistan, suggesting possible breed and environmental influences on production outcomes.

In conclusion, the data affirm that concentrate supplementation is a reliable and efficient strategy to boost milk yield in lactating camels under semi-intensive management systems, particularly in arid and semi-arid regions.

The lack of significant variation in milk yield improvements among the three locations suggests that the concentrate supplementation had a consistent positive impact on lactating camels regardless of regional differences in baseline productivity or environmental conditions. This consistency underscores the reliability and generalizability of the feeding intervention across diverse semi-intensive systems in the Red Sea State.

Although numerical differences were observed, such as the slightly higher baseline and post-supplementation yields in Sinkat, these may be attributed to factors such as individual animal variation, pasture quality, or farm-level management practices, none of which exerted a statistically significant influence on the outcome.

These findings are in agreement with other studies reporting improved camel milk yield under semi-intensive systems with supplementation (Hasan et al., 2023 and Dereje et al., 2016) and support the recommendation for standardized concentrate feeding protocols in peri-urban camel production systems.

Conclusions and recommendations

It could be concluded that offering 2 kg of concentrate after gazing for 7 hours displayed a highly significant increase in camel milk yield. Further studies are encouraged to explore the use of concentrate supplementation in dromedary camels, aiming to enhance both milk composition and reproductive performance.

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