RESEARCH ARTICLE Indian Journal of Animal Research, Volume 60 Issue 6: 1096-1102 (June 2026)

Potential Milk Production and Blood Characteristics of Majaheem and Sofor Camels Reared under Extensive Management System

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10.18805/IJAR.BF-2069

ABSTRACT

Background: Milk production, physiological and biochemical traits have been shown to be highly influenced by the environment and management systems of different mammalian species.

Methods: At a camel farm in the Al-Ahsa region, Majaheem and Sofor camels were monitored for the productive, physiological and biochemical traits. These camels were bred using an extensive management system, which typically involves free-ranging with minimal human intervention. Twenty she-camels of Majaheem and Sofor were monitored for recording lactation period, milk production and composition, reproductive efficiency and physiological indicators (rectal temperature, pulse rate and SPO_2). In addition, blood samples were collected for determination of health profiles (hematological and biochemical traits).

Result: The results indicated that Majaheem breed had higher lactation period, milk production in addition to higher fat, protein, lactose and mineral (%) as compared to Sofor breed. Sofor she-camels needed fewer inseminations to get pregnant compared to Majaheem she-camels. The Majaheem she-camels had significantly lower ($P<0.05$) RBCs, PCV, Hb and WBCs compared to Sofor she-camels. In addition, the Majaheem she-camels had significantly lower values in all of plasma biochemical profiles when compared to Sofor she-camels. In conclusion, productive, reproductive and health profile characters might be different due to breed variation and/or milk production.

Key words: Biochemistry, Blood, Majaheem, Milk, Physiology, Reproduction, Sofor.

INTRODUCTION

Camel herding over the last two decades has demonstrated a recent surge of interest that is noticed as the camel population has increased by around 46.0% between 2001 and 2018 as compared to 6.0% in the previous two-decades (1981-2000) at the global scale (FAO 2020). As the climate gets warmer and it becomes harder to maintain traditional livelihoods in dry regions, researchers are increasingly focusing on how different breeding systems affect the population and productivity of animals (Faye 2018, 2019; Julien *et al.,* 2021; Amsidder *et al.,* 2024).

The Majaheem is a prominent and highly valued camel breed in Saudi Arabia, known for its distinctive characteristics and its importance to the country's heritage (Mohammed and Alshaibani, 2025). Majaheem she-camels are easily identified by their large size and a uniform black coat, which can range from dark brown to a very dark (Dioli *et al.,* 2023). They have long legs, wide feet and a well-developed udder (Dioli, 2016). The Majaheem breed is believed to have originated in Saudi Arabia, particularly in the Najd and Dawaser Valley regions in the north and northeast (Alhadrami and Faye, 2016). It is also referred to as "Najdi camels." Historically, they were raised by the Al-Dawasir and Al Murrah tribes before spreading to other tribes (Saudipedia, 2025). While traditionally used for transport, their value as a source of milk and meat has increased and they are a vital part of the livestock economy in arid regions (Amsidder *et al.,* 2024). Like other camel breeds in Saudi Arabia, Majaheem camels are well-adapted to the harsh desert environment, with physiological traits that allow them to endure extreme temperatures, thrive on low-quality forage and survive for long periods without water (Ibrahim *et al.,* 2025). The Majaheem breed is a testament to the long-standing tradition of camel husbandry in Saudi Arabia and continues to play a significant role in the country's culture and economy (Mohammed and Alshaibani, 2025).

The Sofor camel is one of the distinct breeds found in Saudi Arabia, particularly in the desert regions of Najd and

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How to cite this article: Mohammed, A.A., Almuyidi, A., Al-Suwaiegh, S., AlGherair, I. and Alshaibani, N. (2026). Potential Milk Production and Blood Characteristics of Majaheem and Sofor Camels Reared under Extensive Management System. *Indian Journal of Animal Research*. **60(6):** 1096-1102. doi: 10.18805/IJAR.BF-2069.

Submitted: 14-09-2025 **Accepted:** 14-10-2025 **Online:** 29-10-2025

Riyadh (Ibrahim *et al.,* 2025). It is known for its unique coloration and is recognized in major camel beauty competitions, which often classify breeds by their coat color (Tharwat and Al-Hawas, 2023; Tharwat *et al*., 2024). The most defining feature of the Sofor camel is its coat color, which is a yellow-brown or a blend of white and red. This coloration helps distinguish Sofor from other prominent breeds like the black Majaheem or the white Waddah (Maghateer) (Tharwat and Al-Hawas, 2023; Mohammed and Alshaibani, 2025). Sofor are considered a type of desert camel and are well-adapted to the harsh conditions of these regions (Ibrahim *et al.,* 2025). The Sofor breed is indigenous to the desert areas of Saudi Arabia, particularly in the central and northern parts of the country (Almathen *et al.,* 2022). They are often grouped with other desert-dwelling breeds like the Majaheem and Shul, which have evolved to thrive in the arid climate of the Najd and Riyadh regions. Like many other camel breeds in the Arabian Peninsula, the Sofor camel is a multipurpose animal. While they are a source of milk and meat, the Sofor camels are highly valued in the camel beauty competitions (known as "Mezayen"), where their specific appearance and physical traits are judged. This has elevated their cultural and economic importance beyond simple utility. Therefore, the aim of the current study is to investigate the physiological and biochemical characteristics in addition to milk production and composition of Majaheem and Sofor camel breeds under extensive management system in Al-ahsaa region.

MATERIALS AND METHODS

The experimental process and procedures were reviewed and approved by the ethical committee at King Faisal University (KFU-REC-2025-NOV-EA252980). All experimental work was conducted at the animal laboratory within the College of Agriculture and Food Sciences at the same university.

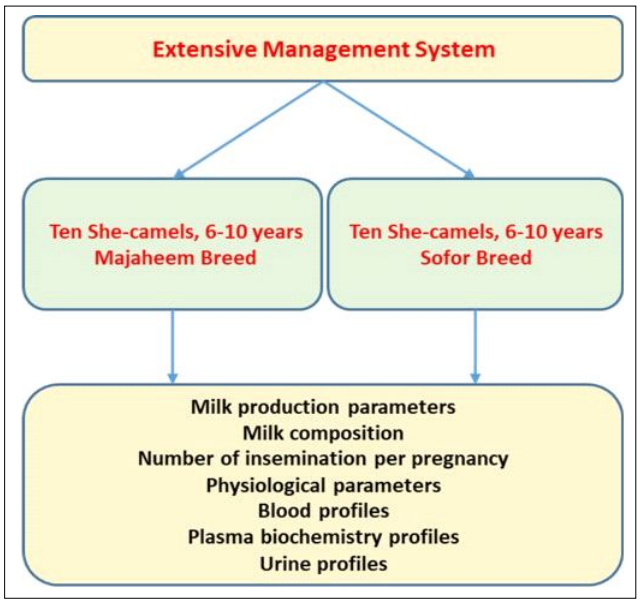

Fig 1: The experimental design of a study in Majaheem and sofor she-camels.

Site of study and animal management

This study, which ran from October 2024 to August 2025, focused on 10 Majaheem and 10 Sofor she-camels (Fig 1 and Fig 2A, 2B). These camels were managed extensively through free grazing. All the camels were multiparous and were between 6 and 10 years old, with lactation stage ranging from 9 to 11 months. In addition to grazing, their diet was supplemented with 7.0 kg berseem hay. The range environmental conditions during the study were a temperature of 22.0-46.0°C and a relative humidity of 30.0-48.0%.

Monitoring milk production and composition

The milk production of Majaheem and Sofor she-camel was recorded monthly through hand milking after parturition during the lactation season. The udders of she-camels were cleaned prior to hand milking and the milk yield per head (liter/head) was recorded. The first three milk squirts were discarded and the udder was completely emptied in a plastic sterilized container. The collected milk samples were determined (kg/head) and samples subsequently underwent chemical analyses (total solids, protein, fat, lactose and minerals). The milk chemical compositions of Majaheem and Sofor breeds were determined using milkoscan apparatus over five months of lactation.

Reproductive performance was evaluated by the number of inseminations, after calving, per Majaheem and Sofor she-camels until confirmation of pregnancy.

The Majaheem and Sofor she-camel were investigated for recording of pulse rate (beats/min.), partial pressure of oxygen (%) and rectal temperature (°C). Pulse rate and partial pressure of oxygen were monitored using pulse oximeter device (CMS60D-VET). Rectal temperatures were monitored using clinical thermometer (Citizen) (Mohammed *et al.,* 2025 a,b,c; Mohammed and Alshaibani, 2025).

Blood sample collection and analyses

Blood samples were collected from the jugular veins of Majaheem and Sofor she-camel after observing all sterile measures. The collected blood samples were analyzed using automatic hematology analyzer (Mythic 5Vet PRO) and biochemistry analyzer (Mythic 5Vet PRO).

Statistical analysis

Milk production and composition, number of insemination per pregnancy, pulse rate, SPO2, rectal temperature, blood and plasma biochemistry profiles of Majaheem and Sofor she-camels were statistically analyzed using T-test procedure to compare between the means of two the groups using SAS 2008 statistical program according to model:

$$Yij = \mu + Ti + eij$$

Where,
μ = Mean.
Ti = Effects of Majaheem and Sofor she-camels.
Eij = Standard error.

Duncan's multiple range test (1955) was used to compare between means of Majaheem and Sofor she-camels.

RESULTS AND DISCUSSION

Milk yield of two camel breeds, Majahim and Sofor, over a 10-month period is presented in Fig 3. Overall, the Majaheem she-camels consistently produced a higher milk yield than the Sofor she-camels throughout the entire 10-month lactation period. Both Majaheem and Sofor breeds reached their peak milk yield in month 5. The Majaheem camels peaked at approximately 7.5 kg of milk per day, while the Majaheem camels peaked at around 5.57 kg per day. After peaking in month 5, the milk yield for both types of camels steadily declined for the remainder of the 10-month period. Collectively, the data clearly demonstrates that the Majaheem breed is a superior milk producer compared to the Sofor breed in terms of milk yield across the entire 10-month lactation cycle.

Chemical milk composition

The study found significant differences in the milk composition between Majaheem and Sofor camels (Table 1). Majaheem milk had a significantly higher (P<0.05) average fat percentage (2.38%) compared to Sofor camels (1.79%). Majaheem milk had a higher average (8.25%) of SNF than Sofor camels (8.00%). There was no significant difference in the protein percentage between the two breeds. Majaheem milk averaged 3.03% and Sofor camels averaged 2.97% of total protein. Majaheem milk showed a significantly higher (P<0.05) average lactose percentage (4.42%) compared to Sofor milk (4.33%). Majaheem milk had a significantly higher average mineral content (0.67%) than Sofor milk (0.53%). There were no significant differences in milk density (P=0.06) or freezing point (P=0.05) between the two breeds.

Physiological parameters, productive and reproductive parameters

Physiological parameters, productive and reproductive parameters of Majaheem and Sofor she-camel breeds is presented in Table 2. The Sofor camels had significantly (P<0.03) lower rectal temperature (37.52°C) compared to the Majaheem camels (37.73°C). There were no significant differences in pulse rate or blood oxygen saturation (SPO2) between the two breeds. The Sofor she-camels required a significantly (P<0.0001) lower number of inseminations per pregnancy (2.16) than the Majaheem she-camels (2.75). The Majaheem she-camels had a significantly (P<0.01) longer lactation period (315.0 days) than the Sofor she-camels (290.0 days). Majaheem she-camels demonstrated a significantly higher daily milk production (4.80 L) compared

Fig 2: Camel breeds; Majaheem she-camels (A), Sofor she-camel (B).

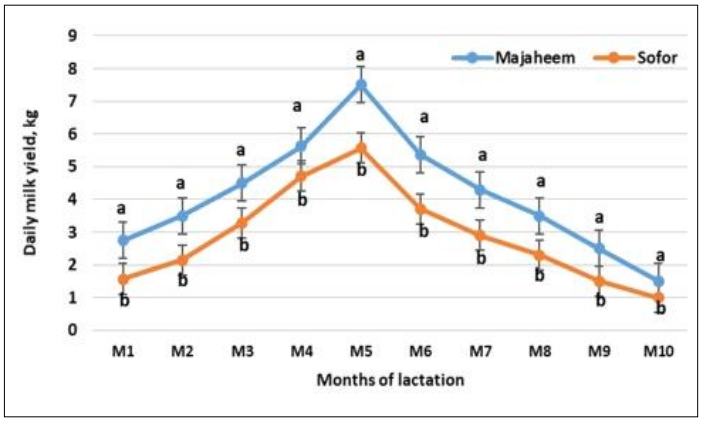

Fig 3: Milk production during lactation period.

to the Sofor camels (3.50 L). There was no significant difference in open days between the two breeds.

In conclusion, the data indicates that while Sofor camels have a better reproductive efficiency (fewer inseminations needed for pregnancy), the Majaheem she-camels are superior in terms of milk production and have a longer lactation period. Additionally, Sofor she-camels have a significantly lower rectal temperature, which may indicate a difference in their physiological response.

Hematological and plasma biochemical analysis

Concerning to hematology investigation (Table 3), the analysis revealed significant differences in all measured blood parameters between the Majaheem and Sofor breeds. The Sofor she-camels consistently showed higher values compared to the Majaheem she-camels. The Sofor camels had a significantly (P<0.01) higher RBCs count (8.10×10^6/µl) than the Majaheem camels (7.50×10^6/µl). The packed cell volume (PCV) was significantly (P<0.05) higher in Sofor camels (28.3%) compared to Majaheem camels (25.10%). Sofor camels had a significantly higher hemoglobin concentration (12.20 g/dl) than Majaheem camels (11.30 g/dl). The Sofor breed showed a significantly (P<0.0001) higher total white blood cell count (16.90×10^3/µl) than the Majaheem breed (15.80×10^3/µl). In summary, the Sofor camels demonstrated significantly higher values for all hematological parameters, suggesting a distinctive physiological difference between the two breeds.

Table 1: Chemical milk composition of Majaheem and Sofor camel breeds at peak of lactation.

Parameters, %	Majaheem	Sofor	SEM	P value
Fat	2.38[a]	1.79[b]	0.26	<0.0001
Solids non fat	8.25[a]	8.00[b]	0.31	0.05
Protein	3.03	2.97	0.12	0.07
Lactose	4.42[a]	4.33[b]	0.17	0.05
Minerals	0.67[a]	0.53[b]	0.032	0.001
Density	1.025	1.020	0.001	0.06
Freezing point	-0.46	-0.41	0.109	0.05

[a,b] Values between groups with different superscripts significantly differ at P<0.05.
SEM: Standard error.

The values of plasma biochemical profiles of Majaheem and Sofor breeds are presented in Table 4. The Majaheem group had significantly lower values in all of plasma biochemical profiles if compared to Sofor group. The analysis revealed several significant differences in plasma biochemistry between the Majaheem and Sofor breeds. The Sofor camels generally had higher values for most of the measured parameters. Sofor camels had a significantly higher total protein concentration (6.55 g/dl) compared to Majaheem camels (6.15 g/dl). Both urea (25.0 mg/dl vs. 18.5 mg/dl) and creatinine (2.0 mg/dl vs. 1.60 mg/dl) concentrations were significantly higher in the Sofor breed. The Sofor breed had a significantly higher blood glucose level (125.0 mg/dl) than the Majaheem breed (111.5 mg/dl). Creatine kinase (CK) activity was significantly higher in Sofor camels (82.0 U/l) than in Majaheem camels (72.5 U/l). Lactate dehydrogenase (LDH) activity was also significantly higher in Sofor camels (795.0 U/l) compared to Majaheem camels (730.0 U/l). The Sofor breed had a highly significant higher iron concentration (92.0 µg/dl) than the Majaheem breed (83.0 µg/dl). γ-glutamyl transferase (GGT) activity was significantly higher in Sofor camels (70.0 U/l) than in Majaheem camels (63.5 U/l). The values of aspartate aminotransferase (AST), alanine amino-transferase (ALT) and Copper were not different between the two breeds.

Based on the comprehensive results presented across the provided (Fig 3 and Table 1-2), the most striking finding was the clear distinction in milk productivity between the Majaheem and Sofor breeds. The Majaheem camels exhibit a significantly higher daily milk yield, peaking at approximately 7.5 kg in the fifth month of lactation, than Sofor breed. This suggests that the Majaheem is a high-yielding dairy breed with a strong initial lactation curve as indicated in other studies (El-Hanafy *et al*., 2023). In addition, the Majaheem camels have a significantly longer lactation period (315 days) compared to the Sofor camels (290 days). This implies that Majaheem camels are ideal for high-volume milk production and long-term milk supply. In terms of reproductive efficiency, the Sofor breed demonstrates a significant advantage, requiring fewer inseminations per pregnancy (Mohammed and Al-Mutairi 2012). This indicates higher fertility and this could make them a more

Table 2: Physiological parameters, reproductive and productive parameters of blood profiles of Majaheem and Sofor she-camel breeds.

Parameters	Majaheem	Sofor	SEM	P value
Rectal temperature, °C	37.73[a]	37.52[b]	0.14	0.03
Pulse rate, min.	67.3	63.81	1.13	0.07
SPO_2, %	79.3	81.3	2.15	0.08
Open days	346.0	332.0	4.10	0.08
No. insemination/pregnancy	2.75[a]	2.16[b]	0.27	<0.0001
Lactation period, days	315.0[a]	290.0[b]	10.0	0.01
Daily milk production, kg	4.80[a]	3.50[b]	0.20	<0.0001

[a,b] Values between groups with different superscripts significantly differ at P<0.05.
SEM: Standard error.

economically efficient choice for large-scale breeding programs.

Both breeds follow a typical lactation curve, with milk production starting at a moderate level, peaking and then gradually declining. Milk yield for both breeds peaks in the fifth month of lactation. The peak yield for Majaheem camels is approximately 7.5 kg/day, while for Sofor camels, it is around 5.5 kg/day.

The figure highlights the clear superiority of the Majaheem breed in milk production as indicated in other study (El-Hanafy *et al.,* 2023). For every month of lactation shown, Majaheem camels consistently produce a higher daily milk yield than Sofor camels. Majaheem camels begin their lactation with a daily yield of over 2.5 kg, while Sofor camels start below 2 kg. The gap between the two breeds widens as they approach their peak production. The difference is most pronounced at the peak of lactation in month 5. The consistent and statistically significant difference in daily milk yield over the entire lactation period confirms that Majaheem camels are the preferred choice for milk production. The lactation curve for Majaheem is not only higher at the peak but also maintains a higher level of production for a longer duration, contributing to a greater total milk yield over the curve of the lactation.

Milk composition

The results of milk composition indicate clear differences in milk composition between Majaheem and Sofor she-camels under an extensive management system (Table 1). This study demonstrates that under extensive management system, Majaheem camels produce milk with a significantly higher concentration of key components like fat, lactose and minerals compared to Sofor camels. These results are consistent with previous studies that have noted variations in milk composition among camel breeds, often linked to genetics, diet and environmental conditions (Elamin and Wilcox, 1992; El-Hanafy *et al.,* 2023). The extensive management system used in this study, where animals had access to natural grazing, likely played a role in the observed differences. The higher fat and mineral content in Majaheem camels could be a genetic trait that allows them to better utilize the nutrients available in their grazing environment, leading to a richer milk composition.

These findings have several implications for the value and potential use of milk from each breed (Elamin and Wilcox 1992; El-Hanafy *et al.,* 2023). The most notable finding is the significantly higher fat content in Majaheem camel milk compared to Sofor camel milk (P<0.0001). This difference is substantial and suggests that Majaheem camels may be more suitable for products where milk fat is a key component, such as butter or ghee. This higher fat content, along with the significant differences in solids-non-fat (SNF), lactose and minerals, contributes to the overall higher density of Majaheem milk, although the difference in density itself was not significant at the P<0.05 level. The significant differences in SNF, lactose and minerals further highlight the nutritional superiority of Majaheem milk in this study. Higher SNF indicates a richer concentration of non-fat components, which are crucial for the nutritional value of milk. The higher mineral content in Majaheem milk is also a significant finding, as minerals are essential for both human nutrition and the overall quality of the milk. Interestingly, protein content was not significantly different between the two breeds. This suggests that while Majaheem camels may produce milk with higher fat and mineral content, the protein yield per unit of milk is similar between the two breeds. This is a crucial point for dairy processing,

Table 3: Blood profiles of Majaheem and Sofor breeds.

Parameters	Majaheem	Sofor	SEM	P value
RBCs, 10^6/µl	7.50[b]	8.10[a]	0.35	0.01
PCV, %	25.10[b]	28.3[a]	1.66	0.05
Hb, g/dl	11.30[b]	12.20[a]	0.30	0.01
WBCs, 10^3/µl	15.80[b]	16.90[a]	0.66	<0.0001

[a,b] Values between groups with different superscripts significantly differ at P<0.05.

SEM: Standard error; RBCs: Red blood cells; PCV: Packed cell volume; Hb: Hemoglobin; WBCs: White blood cells.

Table 4: Plasma biochemistry profiles of Majaheem and Sofor breeds.

Parameters	Majaheem	Sofor	SEM	P value
Total protein, g/dl	6.15[b]	6.55[a]	0.12	0.01
Urea, mg/dl	18.5[b]	25.0[a]	1.25	0.01
Creatinine, mg/dl	1.60[b]	2.0[a]	0.17	0.01
Glucose, mg/dl	111.5[b]	125.0[a]	7.09	0.05
Aspartate Aminotransferase, U/l	133.0[b]	129.0[a]	2.13	0.08
Alanine aminotransferase, U/l	27.0[b]	28.0[a]	1.30	0.09
γ-glutamyl transferase, U/l	63.5[b]	70.0[a]	1.19	0.05
Creatine kinase, U/l	72.5[b]	82.0[a]	1.33	0.05
Lactate dehydrogenase, U/l	730.0[b]	795.0[a]	16.58	0.01
Iron, µg/dl	83.0[b]	92.0[a]	3.52	<0.0001
Cupper, µg/dl	71.0	73.0	1.15	0.07

[a,b] Values between groups with different superscripts significantly differ at P<0.05.

SEM: Standard error.

as protein is a key ingredient in cheese and other products. The lack of a significant difference in freezing point and density, while other compositional factors were different, suggests a complex interplay between the various milk components. The freezing point is influenced by the concentration of lactose and minerals and while both were higher in Majaheem milk, the overall effect on the freezing point was not large enough to be statistically significant, possibly due to the small sample size or other unmeasured variables.

Physiological, reproductive and productive traits

The results presented in Table 2 reveal significant differences in physiological, reproductive and productive traits between Majaheem and Sofor camels under the extensive management system. These findings have important implications for understanding the overall performance and adaptability of these breeds. Majaheem camels had a higher average rectal temperature (37.73°C) compared to Sofor camels (37.52°C) ($P<0.03$). This significant difference might suggest a subtle variation in thermoregulatory mechanisms between the two breeds, possibly reflecting their genetic adaptations to the environment due to black color coat. While Majaheem camels had a slightly higher pulse rate and a lower SPO_2, these differences were not statistically significant ($P<0.07$ and $P<0.08$ respectively). This suggests that both breeds are generally similar in their baseline cardiovascular and respiratory functions under these conditions. The slight trends, however, may warrant further investigation with a larger sample size.

A highly significant finding is that Sofor camels required significantly fewer inseminations per pregnancy (2.16) compared to Majaheem camels (2.75) ($P<0.0001$). This indicates that Sofor camels have better reproductive efficiency, which is a crucial factor for the economic *via*bility of a breeding program. Fewer inseminations translate to lower costs and shorter breeding intervals, making Sofor camels potentially more profitable from a reproductive standpoint. This could be attributed to higher milk production in Majaheem camels with an inverse relationship between milk production and reproductive performance (Antanaitis *et al.,* 2024). No significant differences were found in the number of open days between the two breeds. This suggests that both breeds have similar reproductive cycles and that the difference in insemination success is the primary factor affecting their reproductive efficiency, rather than the length of their reproductive cycles. Majaheem camels demonstrated superior milk-producing capabilities. Majaheem camels significantly outperformed Sofor camels in key dairy metrics under the extensive management system. The Majaheem demonstrated superior productivity with an average daily yield of 4.80 L, substantially higher than the Sofor's 3.50 L. Furthermore, Majaheem maintained this production for a considerably longer lactation period (315 days) compared to the Sofor (290 days). These strong differences indicate that Majaheem is the more suitable and productive dairy breed of the two.

Hematological and biochemical traits

The observed differences in milk yield and reproductive efficiency are well-supported by the hematological and biochemical traits (Table 3 and 4). The data reveals several significant differences in blood characteristics, which can offer insights into the physiological state and health of each breed under the extensive management system (Table 3). Surprisingly, the Majaheem camels had a slightly but significantly lower RBC count ($7.50\times10^6/\mu l$) compared to Sofor camels ($8.10\times10^6/\mu l$). Correspondingly, Majaheem camels also showed significantly lower values for both packed cell volume (PCV) and hemoglobin (Hb) compared to Sofor camels. The PCV was 25.10% in Majaheem versus 28.3% in Sofor ($P<0.05$) and Hb was 11.30 g/dl versus 12.20 g/dl ($P<0.01$). These three parameters (RBC, PCV and Hb) are all related to the oxygen-carrying capacity of the blood. The consistently lower values in Majaheem camels suggest that their blood is less dense in red blood cells and carries less oxygen per unit volume compared to Sofor camels. This could be a physiological adaptation or a reflection of nutritional status. Given that Majaheem camels are noted for higher milk production, their body may be prioritizing nutrient allocation to milk synthesis over red blood cell production, although this is a hypothesis that would require further investigation. Alternatively, it might simply be a breed-specific trait.

Sofor camels had a significantly higher average WBCs count ($16.90\times10^3/\mu l$) compared to Majaheem camels ($15.80\times10^3/\mu l$). A higher WBCs count is often an indicator of an ongoing inflammatory response, infection, or stress. The significantly higher count in Sofor camels, while potentially within a normal range, suggests that they might be experiencing a higher level of physiological stress or are more prone to subclinical infections compared to the Majaheem breed under the conditions of this study. It is also possible that this is a normal breed-specific difference in immune system activity.

The lower blood concentrations of glucose, urea, creatinine, total protein and key metabolic enzymes like lactate dehydrogenase (LDH) and creatine kinase (CK) in Majaheem camels strongly suggest a higher basal metabolic rate (Table 4). Lactation is a highly energy-demanding process and the decreased levels of glucose and protein are likely a direct physiological response to meet the demands of producing a greater volume of milk. The lower levels of urea and creatinine could be linked to increased protein anabolism, which is characteristic of highly productive animals. In conclusion, this comprehensive analysis of physiological, reproductive and biochemical parameters confirms that Majaheem and Sofor camels represent distinct breeds with unique adaptive and productive characteristics. These findings are crucial for developing targeted breeding strategies and optimizing camel management for specific economic and ecological objectives.

CONCLUSION

The results show a clear trade-off between the two breeds. Sofor camels exhibit better reproductive efficiency, requiring fewer inseminations to achieve pregnancy. In contrast, Majaheem camels are superior in dairy productivity, with a longer lactation period and a significantly higher daily milk yield. These findings are critical for farmers and breeders in the Al-Ahsaa region. The differences in physiological parameters, while significant in some cases are likely a reflection of these underlying productive and genetic traits.

ACKNOWLEDGEMENT

This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [KFU253503].

Funding

Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [KFU253503].

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions.

Informed consent

The Ethical Committee of Deanship of Scientific Research, King Faisal University, Saudi Arabia, approved all animal experimental cares (KFU KFU253503).

Conflict of interest

No conflict of interest to declare for authors.

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