DRF-330
[1-5]

RESEARCH ARTICLE Asian Journal of Dairy and Food Research

Effects of Season, Productive State, Age and Agro-ecology on Blood Biochemical Characteristics of Dromedary Camels (*Camelus dromedarius*) in Natural Browsing Environment

W.J. Roba[1], K.K. Yisehak[1], A.G. Asrat[1]

10.18805/ajdfr.DRF-330

ABSTRACT

Background: Blood biochemistry and reference intervals assist in distinguishing between healthy and productive camels as well as providing information for nutritional conditions, evaluation and monitoring when they are allowed to browse naturally; nevertheless, these intervals are frequently collected from animals of varying ages. The nutritional condition and biochemical markers of dromedary camels in pastoral systems in southern Ethiopia were investigated in this study, which took season, animal status, age and environmental variables into consideration.

Methods: A total of 36 camels were divided into three groups based on their age (> 8 years, 5-8 years, or less than 5 years) and productive state (milking, pregnant and young) in two environments (two herds in arid and semi-arid areas). Blood samples were collected from animals' neck jugular veins, centrifuged and frozen for analysis. The samples were centrifuged (3000 rpm for 10 min) immediately after their arrival at the laboratory. Serum concentrations of glucose, protein, urea, creatinine, triglycerides and cholesterol were measured using spectrophotometry.

Result: This study shows that glucose (91.33+7.30 mg/dl), total protein (7.17+0.15 mg/dl) and triglyceride (75.28+5.38 mg/dl) concentrations were significantly higher ($P<0.05$) during the rainy season, whereas urea (32.06+1.18 mg/l) and creatinine levels were significantly higher during the dry season. The study reveals increased glucose, total protein and triglyceride concentrations in camels during the rainy season, while urea and creatinine levels were higher during the dry season. Arid camels had lower serum concentrations of total protein and urea. Milking and pregnant camels had lower total serum protein, triglyceride and cholesterol levels.

Key words: Blood biochemistry, Borana, *Camelus dromedarius*, Productive state, Protein.

INTRODUCTION

The camel (*Camelus dromedarius,* or one-humped camel) is a very dominating and widely distributed animal in Sub-Saharan Africa, particularly in the least developed countries. It is critical to human life and utilisation in dry and desert areas. In the face of growing desertification and the recurrence of drought and famine in Sub-Saharan Africa, particularly in East Africa, the camel plays an important role as a source of milk, meat and draught power. The camel's main purpose is directly tied to its exceptional tolerance to exceedingly severe situations and it can thrive where no other household animal can (Oselu *et al.*, 2022; Rahimi *et al.*, 2022).

Camel productivity is limited by inadequate nutrition (Hamad *et al.*, 2018; Xulu *et al.*, 2022). Animal nutritional status is important since it is a basic measure of animal health and productivity because the entire production system is built on traditional and vast poor rangelands that have typically deteriorated due to a variety of factors (Yagil and Etzion, 1980). Camel nutritional status and thus blood contents, appear to be important, as do blood value comparisons under different management systems, because these values represent the animal's well-being (Abdoun *et al.*, 2011; Ogunbosoye *et al.*, 2015). Furthermore, camel nutrition is often the outcome of a series of interconnected factors such as season and environment. The nutritional composition and physical qualities of the forage available in various settings and seasons in the ration, on the other hand, have a significant impact on camel food utilisation (Abd El-Salaam and Arafa, 2018). Payne *et al.* (1970) and Lamo *et al.* (2020) detected nutritional inadequacies by examining biochemical features of animal blood.

Blood metabolites are increasingly being used to determine an animal's nutritional status (Momenah, 2014; Faraz *et al.*, 2022). Blood constituent analysis can provide

[1]Department of Animal Sciences, College of Agricultural Sciences Arba Minch University, P.O. Box 21, Arba Minch, Ethiopia.

Corresponding Author: W.J. Roba, Department of Animal Sciences, College of Agricultural Sciences Arba Minch University, P.O. Box 21, Arba Minch, Ethiopia. Email: rjelema@gmail.com

How to cite this article: Roba, W.J., Yisehak, K.K. and Asrat, A.G. (2023). Effects of Season, Productive State, Age and Agro-ecology on Blood Biochemical Characteristics of Dromedary Camels (*Camelus dromedarius*) in Natural Browsing Environment. Asian Journal of Dairy and Food Research. DOI: 10.18805/ajdfr.DRF-330.

Submitted: 18-04-2023 **Accepted:** 25-10-2023 **Online:** 16-11-2023

useful information about an animal's overall health (Babeker *et al.*, 2013; Momenah, 2014). Blood metabolite levels, on the other hand, reveal the extent of energy, protein and other nutrition metabolism in animals Faraz. (2021). Serum metabolite profiling, without a doubt, provides more information than body condition rating (Faye and Bengoumi 2018; Worku *et al.*, 2021). Blood biochemical studies provide a wealth of information about an animal's nutritional health and well-being and can thus be used to assess overall health. It has the potential to be a valuable tool for monitoring camel health (Faraz *et al.*, 2020). The nutritional health of dromedary camels has never been studied before in the Boran Plateau and this is the first study of its sort. Obtaining data on blood biochemical profiles could thus serve as a foundation for future study and planning. As a result, the objectives of this study were to establish the nutritional condition of wild browsing dromedary camels of varied ages and productive statuses using blood serum variables and to assess the influence of seasonal and environmental factors.

MATERIALS AND METHODS

The experiment samples were collected in April and October 2022 in two areas of the Borana Zone in Southern Ethiopia: hot lowland (Gamojji) and semi-arid (Badda Dare). This classification is based on annual and monthly mean temperature and rainfall, seasonal changes in rainfall and native vegetation type. The hot lowland (Gamojji) is located at 04°95.72′ latitude, 037°80.91′ longitude and 1116 m elevation. The semi-arid (Badda Dare) region is located at 05°11.04′ latitude and 038°27.46' longitude, with an elevation of 1650 m. Rainfall in the study areas is bimodal, with a mean annual rainfall of 500 mm and significant inter-annual variability (Angassa and Oba, 2007). The main rainy season (Mid-March to Mid-May) accounts for 70% of annual rainfall, while the short rainy season (Mid-September to Mid-November) accounts for 30% (Megersa *et al.*, 2014).

A total of 36 camels from two herds in two Borana plateau agroecology were used for blood sampling. The camels were classified into three groups (G) based on their age (>8 years, 5-8 years, or less than 5 years) and productive status (milking, pregnant, or young). In arid and semi-arid agroecology G1 consists of 12 milking camels, G2 consists of 12 pregnant camels and G3 consists of 12 young males and females. We confirm that we followed international standards for research animal ethical protection. The samples were taken during the wet and dry seasons. Blood was drawn from the jugular veins of the animals. The centrifugation (3000 rpm/ 20 minutes) was used to separate the blood plasma sample from the serum (Abd El-Salaam and Arafa, 2018; Hamad *et al.*, 2018; Mohammed *et al.*, 2021).

The samples were placed on ice at about -18°C and transported to the laboratory for biochemical analysis on the same day. Several biochemical parameters, including serum glucose, triglyceride, cholesterol, urea, serum creatinine and total protein, were measured using commercial diagnostic kits (MINDRAY BA-88A Semi-Auto Chemistry Analyser) (Adjorlolo *et al.*, 2019).

The data were analysed using statistical analysis software (SAS, version 9.0) in accordance with multivariate analysis protocols. Means and standard error of mean were used to present the data. The means of various age groups and productive/reproductive statuses were compared using an analysis of variance (ANOVA). The statistical means of two seasons (dry and wet) and settings (arid and semi-arid) were compared using the independent-samples approach. The overall level of statistical significance for the ANOVA and t-test was set at $P < 0.05$.

$$Y_{ijkl} = \mu+\alpha_i + \beta_j + \gamma_k + \Sigma_{ijkl}$$

Where,

α_i = The i^{th} effect of season (i=1,2).

β_j = The j^{th} effect of environment/agro- ecology (j=1, 2).

γ_k = The k^{th} effect of age of camels (k= 1, 2, 3).

δ_l= The l^{th} effect of animal status(reproduction/production) (l= 1,2,3).

RESULTS AND DISCUSSION

Effect of season on profiles of camels

Table 1 illustrates the effect of season on blood biochemical parameters of camels. The average concentrations of glucose, triglycerides and cholesterol during the rainy season are 91.33±7.30, 75.28±5.38 and 80.28±7.87, respectively. Glucose, total protein and triglyceride levels were higher in the rainy season than in the dry season ($P<0.05$), but cholesterol levels were not statistically significant ($p<0.05$). During the dry seasons, however, the mean values of total protein, urea and creatinine were 7.17 0.15, 32.0±61.18 and 2.06±0.05, respectively, the result is significantly higher than during the rainy season ($P<0.05$). This result is in line with those of Faraz *et al.* (2020), Worku *et al.* (2021) and Faraz *et al.* (2022), who revealed that camel nutritional status can be evaluated using biochemical parameters and that nutritional status changes by season and geographic location. Serum biochemical parameters (glucose, cholesterol and urea) varied significantly ($P<0.05$) between dry and rainy seasons. Aichouni *et al.* (2013) stated that seasonal fluctuations in triglyceride and cholesterol concentrations were found, but there was no effect on plasma glucose, serum urea, or creatinine concentrations. This findings is in line with Dar *et al.* (2019) Serum glucose levels and total proteins increase during rainy seasons, while serum, triglycerides, cholesterol, creatinine and urea levels decrease during dry seasons. Seasonal variations in biochemical levels are observed. However, no significant differences ($P< 0.05$) in biochemical parameters (total protein, albumin and globulin) were observed with respect to age, despite the fact that the highest values of all serum biochemical parameters were reported during the rainy and the lowest values during the dry (Jan and Ahmed, 2021).

Worku *et al.* (2021) discovered that serum creatinine levels were higher ($P<0.001$) during the dry season than

Table 1: Seasonal variations in blood serum parameters in camels (values are mean ±SEM).

Parameter (mg/l)	Seasons		Overall mean ± SEM	P value
	Rainy season	Dry season		
Glucose (mg/dl)	91.33±7.30[a]	60.31±6.09[b]	75.82±5.07	0.002
Total protein (g/dl)	6.65±0.16[a]	7.17±0.15[b]	6.91± 0.11	0.019
Urea (mg/dl)	23.17±1.04[b]	32.06±1.18[a]	27.61±0.94	0.001
Creatinine (mg/dl)	1.35±0.08[b]	2.06±0.05[a]	1.71±0.06	0.001
Triglyceride (mg/dl)	75.28±5.38[a]	56.47±5.84[b]	65.88±4.09	0.021
Cholesterol (mg/dl)	80.28±7.87	76.14±8.41	78.21±5.72	0.720

a,b values with different letters in the same row are significantly different with p≤0.05.

Table 2: The mean ± SEM variation in blood serum of camels aged > 8 years (N= 12), 5-8 years (N= 12) and less than 5 years (N= 12).

Parameters	> 8 years (N= 12)		5-8 years (N= 12)		< 5 years (N= 12)		P-value
	Mean ± SEM	Min ± Max	Mean ± SEM	Min ± Max	Mean ± SEM	Min ± Max	
Glucose (mg/dl	87.46±12.13	37.50±173.00	77.75±6.37	44.50±108.50	62.25±1.31	56.50±70.00	0.05
Total protein (g/dl)	6.65±0.14	5.80±7.40	6.82±0.18	5.45±7.50	7.26±0.18[a]	6.15±8.45	0.04
Urea (mg/dl)	28.42±1.74	13.00±39.50	29.54±1.62	20.00±43.00	24.88±0.74	21.00±30.00	0.07
Creatinine (mg/dl)	1.79±0.11	0.95±2.25	1.66±0.10	1.40±2.10	1.57±0.05	1.10±2.00	0.05
Triglyceride (mg/dl)	70.63±6.12[a]	36.00±99.50[b]	66.42±8.76[a]	31.00±91.50[b]	60.58±7.24	30.50±116.50	0.01
Cholesterol (mg/dl)	89.17±9.96[a]	29.00±128.00	82.33±13.40[a]	18.50±151.00	63.13±12.15	17.50±126.00	0.02

a,b values with different letters in the same row are significantly different with p≤0.05.

during the rainy season. According to Ocheja *et al.* (2021), levels of plasma proteins, glucose, total cholesterol, LDL cholesterol and BUN significantly decreased. Due to their propensity to recycle huge amounts of protein for internal use, camels may have higher blood levels of total urea. Serum creatinine and urea levels were higher (P<0.001) during the dry season than during the rainy season, but urea levels were lower, according to Worku *et al.* (2021) and Faraz *et al.* (2022). Heat stress can reduce nutrient intake, for example, accounts for approximately 35% of the decrease in milk yield in Holstein cows (Ocheja *et al.*, 2021).

Effect of ages on serum parameters in browsing camels

The effects of age groups on the concentration of energy and protein parameters are shown in Table 2. In comparison to animals aged 5-8 and younger than 5 years, animals older than 8 years had higher mean concentrations of glucose, creatinine, triglycerides and cholesterol (P<0.05). This study showed greater levels of glucose (mg/dl) 87.46±12.13 in > 8-year-old camels, higher levels of total protein (mg/dl) 7.26±0.18 in < five-year-old camels, higher levels of triglycerides (mg/dl) 70.63±6.12 in > 8-year-old camels and higher cholesterol (mg/dl) 89.17±9.96 in > 8-year-old camels. This findings is in agreement with Sahraoui *et al.* (2016) who reported (mean and SE) an average serum glucose value of 5±2.11 mmol/L, urea and creatinine values of 2.6±0.72 mmol/L and 1±0.39 mmol/L, respectively and lipid values of total cholesterol (1 mmol/L), triglycerides (1 mmol/L) and LDL cholesterol (0.06±0.09 mmol/L). Age and breed all had an effect on blood biochemical markers (Nagy *et al.*, 2014). This could support the hypothesis that aging and changes in nutrition have an effect on serum total protein (TP) concentrations and the majority of protein fractions. This finding is consistent with Elkhair (2019), who revealed haemoglobin variation with age in camels. Other researchers, on the other hand, found that glucose, urea, triglycerides and total cholesterol levels were significantly greater in young camel serum than in adult camel serum (Abdalmula *et al.*, 2023) which is contradicting with these findings. Nollens *et al.* (2020) reported that age is a good variable to compare glucose levels in animals as an indicator of nutritional quality.

Effects of agro-ecological conditions on serum parameters in natural browsing camels

Table 3 shows the effects of agro- ecology (arid and semi-arid environments) on blood biochemical parameters in natural browsing camels in southern Ethiopia. Camel glucose, total protein, triglyceride and cholesterol levels were lower in arid areas than in semi-arid areas (P<0.05). Creatinine (1.86±0.04) and urea (28.28±1.70) serum concentrations were higher in arid camels than in semi-arid camels (P<0.05). These seasonal differences could be attributed to the dromedary camels' increased energy consumption as a result of heat stress (Hoter *et al.*, 2019; Tibary *et al.*, 2020). Despite higher levels of creatinine, which indicate increased muscle breakdown, the same authors reported that during the dry season, less protein was available to support as an energy source. The findings corroborate the findings of Xulu *et al.* (2022), who revealed a link between total protein and creatinine levels.

Effects of production/reproduction status of camels on the serum parameters of browsing camels

The effects of animal productive state on blood biochemical parameters of browsing camels are presented in Table 4.

Table 3: The agro-ecological variation in camel blood serum parameters (n = 36).

Parameter	Agro ecology		Overall mean±SEM	P value
	Arid	Semi -Arid		
Glucose (mg/dl)	86.69 ± 5.07	64.94 ±8.46	75.82 ±5.07	0.031
Total protein (g/dl)	6.73 ±0.15	7.08 ±0.17	6.91 ±0.11	0.119
Urea (mg/dl)	28.28 ±1.81	26.94 ±0.57	27.61 ±0.94	0.484
Creatinine (mg/dl)	1.56 ±0.11^{a}	1.86 ±0.05^{b}	1.71 ±0.06	0.013
Triglyceride (mg/dl)	55.06 ±4.64^{b}	76.69 ±6.31^{a}	65.88 ±4.09	0.007
Cholesterol (mg/dl)	55.78 ±7.11^{b}	100.64 ±7.32^{a}	78.21 ±5.72	0.001

a,b values with different letters in the same row are significantly different with p≤0.05.

Table 4: The effect of animal productivity status on blood Serum parameters.

Parameter	Animal productivity status			Overall mean±SEM	P value
	Milking(n=12)	Pregnant(n=12)	Young(n=12)		
Glucose (mg/dl	82.25 ± 7.58	82.96 ±12.13^{a}	62.25 ±4.57^{b}	75.82 ±5.07	0.167
Total protein (g/dl	6.98 ± 0.17	6.73 ±0.23	7.01 ±0.18	6.91 ±0.11	0.545
Urea (mg/dl	26.13 ±1.64	31.83 ±1.68^{a}	24.88 ±1.24^{b}	27.61 ±0.94	0.004
Creatinine (mg/dl)	1.55 ± 0.12^{a}	1.90±0.09^{b}	1.67±0.10	1.71±0.06	0.058
Triglyceride (mg/dl	61.33± 7.91	65.67±7.37	70.63±6.04	65.88±4.09	0.657
Cholesterol (mg/dl	67.29±11.51	78.17±8.20	89.17±9.64	78.21±5.72	0.300

a,b values with different letters in the same row are significantly different with p≤0.05.

Total protein had mean ± SEM values of 6.90±0.14, 6.57±0.17 and 7.26±0.18 in milking, pregnant and young camels, respectively. In comparison to immature camels, lactating and pregnant camels had considerably higher glucose concentrations (P<0.05). When compared to milking camels, the younger (non-lactating or pregnant) camels had significantly greater levels of cholesterol, triglycerides and total protein (P<0.05). When compared to pregnant or immature camels, milking camels had the lowest triglyceride and cholesterol values (P<0.05).

CONCLUSION

In this study, the impacts of season, agro ecology, age and animal productive condition on the biochemical of camels in natural browsing habitats are presented for the first time. The results of this study demonstrate that varied influences of season, environmental circumstances, age and animals' production/reproduction status clearly altered measures of protein and energy. It was revealed that the blood's biochemical characteristics fell short of the standard. The camel mostly survives due to its physiological adaptation to adverse climatic conditions, even though the observed values for energy and protein were below the threshold value for maintenance of camels. This may help to explain why camels in the study areas were producing even though they were solely reliant on natural browsing and did not get any supplemental nutrient-rich feed. Changes in dietary status may be responsible for the remarkable urea conversion of camels, which may have a significant positive influence in places with a feed shortage.

Conflict of interest: None.

REFERENCES

Abd El-Salaam, A. M. and Arafa, M. M. (2018). Post-partum haematological, biochemical, mineral and hormonal changes in blood of Maghrebian she-camels with different parity orders under Egyptian condition. IOSR J. Agric. Vet. Sci. 11(2): 68-78.

Abdalmula, A., Shmela, M., Alnagar, F., Buker, A., Benashour, F. and Abograra, I. (2023). Blood profile in normal one humped dromedary (*Camelus dromedarius*) camels in libya. Part 4: Effect of Age Variation on Biochemical and Haematological Blood Profile. http://creativecommons.org/licenses/by/4.0/.

Abdoun, K., Alameen, A., Elmagbol, W., Makkawi, T. and Al-Haidary, A. (2011). Assessment of nutritional status in feed deprived one-humped camels. Journal of Camel Practice and Research. 18(2): 209-212.

Adjorlolo, L., Obese, F. Y. and Tecku, P. (2019). Blood metabolite concentration, milk yield, resumption of ovarian activity and conception in grazing dual purpose cows supplemented with concentrate during the post partum period. Veterinary Medicine and Science. 5(2): 103-111.

Aichouni, A., Belhadia, M., Kebir, N. and Aggad, H. (2013). Season influence on serum organic parameters of dromedarius (*Camelus dromaderius*) in Algeria. Biochem. Biotechnol. Res. 1(1): 8-12.

Angassa, A. and Oba, G. (2007). Relating long-term rainfall variability to cattle population dynamics in communal rangelands and a government ranch in southern Ethiopia. Agricultural Systems. 94(3): 715-725.

Babeker, E.A., Elmansoury, Y.H.A. and Suleem, A.E. (2013). The influence of season on blood constituents of dromedary camel *(Camelus dromedarius)*. Online J. Anim. Feed Res. 3(1): 1-8.

Dar, A.H., Kumar, S., Singh, D.V., Sodhi, M., Sharma, R.K., Ghosh, A.K. and Rahman, J.U. (2019). Seasonal variation in blood biochemical characteristics of Badri cattle. Pharma. Innov. 8(9): 147-150.

Elkhair, N. M. (2019). Effect of age on certain urine parameters of young camels (*Camelus dromedarius*). Online J. Anim. Feed Res. 9: 33-37.

Faraz, A. (2021). Blood biochemical and hair mineral profile of camel calves reared under different management systems. Pakistan Journal of Zoology. 53(1): 55-61.

Faraz, A., Tauqir, N.A., Waheed, A., Ishaq, H.M., Hussain, S.M., Mirza, R.H. and Nabeel, M.S. (2022). Haematological and biochemical profile of extensive kept male barela (*Camelus dromedarius*) camel during breeding and non-breeding season. Sarhad Journal of Agriculture. 38(4): 1184-1188.

Faraz, A., Waheed, A., Tauqir, N. A., Mirza, R. M., Ishaq, H. M. and Nabeel, M. S. (2020). Normal blood biochemical parameters of dromedary camel in Pakistan. Adv. Anim. Vet. Sci. 8(10): 1013-1018.

Faye, B. and Bengoumi, M. (2018). Camel Clinical Biochemistry and Hematology. Cham (Switzerland): Springer. (pp. 173-216). DOI: 10.1007/978-3-319-95562-9.

Hamad, B., Aggad, H., Hadef, L. and Adaika, A. (2018). Effect of seasons on blood biochemical parameters in male dromedary camels in Algeria. Indian Journal of Animal Research. 52(5): 678-682.

Hoter, A., Rizk, S. and Naim, H. Y. (2019). Cellular and molecular adaptation of Arabian camel to heat stress. Frontiers in Genetics. 10: 588.

Jan, K. and Ahmed, I. (2021). The influence of sex and season on some hematological and biochemical parameters of snow trout *Schizothorax labiatus* in the Indian Himalayan Region. Fisheries Science. 87: 39-54.

Lamo, D., Gahlawat, G., Kumar, S., Bharti, V. K., Ranjan, P., Kumar, D. and Chaurasia, O.P. (2020). Morphometric, haematological and physio-biochemical characterization of Bactrian (*Camelus bactrianus*) camel at high altitude. BMC veterinary research. *16*(1): 1-9.

Megersa, B., Markemann, A., Angassa, A. and Valle Zárate, A. (2014). The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia. Food Security. 6: 15-28.

Mohamed, R.H., Ali, F. and Nour, S.Y. (2021). Comparative studies on ovarian hormones and hematobiochemical profile of lactating and non-lactating she-camels (*Camelus dromedarius*). Comparative Clinical Pathology. 30: 415-420.

Momenah, M.A. (2014). Some blood parameters of one humped she camels (*Camelus dromedaries*) in response to parasitic infection. Life Science Journal. 11(5): 118-123.

Nagy, O., Tóthová, C. and Kováè, G. (2014). Age-related changes in the concentrations of serum proteins in calves. Journal of Applied Animal Research. 42(4): 451-458.

Nollens, H.H., Haney, N.J., Stacy, N.I. and Robeck, T.R. (2020). Effects of sex, age and season on the variation of blood analytes in a clinically healthy *ex situ* population of bottlenose dolphins (*Tursiops spp.*). Veterinary Quarterly. 40(1): 342-352.

Ocheja, J.O., Halilu, A., Shittu, B.A., Eniolorunda, S.E., Ajagbe, A.D. and Okolo, S.E. (2021). Haematology and serum biochemistry of yearling West African dwarf goats fed cashew nut shell based diets. Veterinary Medicine and Public Health Journal. 2(1): 17-22.

Ogunbosoye, D. O., Tona, G. O. and Otukoya, F. K. (2015). Evaluation of the nutritive value of selected browse plant species in the Southern Guinea Savannah of Nigeria for feeding to ruminant animals. British Journal of Applied Science and Technology. 7(4): 386.

Oselu, S., Ebere, R., Huka, G., Musalia, L., Marete, E., Mathara, J.M. and Arimi, J.M. (2022). Production and characterisation of camel milk yoghurt containing different types of stabilising agents. Heliyon. 8(11): e11816.

Payne, J.M., Dew, S.M., Manston, R. and Faulks, M. (1970). The use of a metabolic profile test in dairy herds. Veterinary Record. 87: 150-158.

Rahimi, J., Fillol, E., Mutua, J.Y., Cinardi, G., Robinson, T. P., Notenbaert, A. M. and Butterbach-Bahl, K. (2022). A shift from cattle to camel and goat farming can sustain milk production with lower inputs and emissions in north sub-Saharan Africa's drylands. Nature Food. 3(7): 523-531.

Sahraoui, N., Doudou, A., Douadji, O., Babelhadj, B. and Hornick, J.L. (2016). Impact of natural vegetation on some biochemical parameters of the Arabian camel (*Camelus dromedarius*) in Algeria. J. Camelid Sci. 9: 62-71.

Tibary, A. and El Allali, K. (2020). Dromedary camel: A model of heat resistant livestock animal. Theriogenology. 154: 203-211.

Worku, K., Kechero, Y. and Janssens, G. P. (2021). Measuring seasonal and agro-ecological effects on nutritional status in tropical ranging dairy cows. Journal of Dairy Science. 104(4): 4341-4349.

Xulu, T. G., Ncobela, C. N. and Kunene, N. W. (2022). Influence of season and rangeland-type on serum biochemistry of indigenous Zulu sheep. Open Agriculture. 7(1): 455-464.

Yagil, R. and Etzion, Z. (1980). Hormonal and behavioural patterns in the male camel (*Camelus dromedarius*). Reproduction. 58(1): 61-65.