

Bactrian camels (*Camelus bactrianus*) has physio-biochemical adaptation to high altitude

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Abstract

The high altitude region of India is characterized by harsh climatic conditions that may have an adverse impact on growth and metabolic functions of camels. Thus, the main aim of this study was to evaluate different adaptation parameters related to morphological, physio-biochemical and haematological indices in low lander Dromedarian and high lander native Bactrian camels at high altitude. To the best of our knowledge, no studies have been conducted so far to evaluate these different adaptation parameters in both breeds of camels to understand their adaptive mechanism in high altitude. Therefore, the present study was conducted to evaluate these adaptation parameters in Dromedarian and Bactrian camels. All morphological parameters were within the normal ranges in both the breeds. However, girth of hump, and skin thickness of shank and abdomen were towards the higher side of normal range in Dromedarian camels. The heart rate was significantly high and rectal temperature was low in Dromedarian camels than native Bactrian camels ($P < 0.05$). Interestingly, the erythrocytes sedimentation rate, lymphocytes and platelets counts were significantly high and above the reference range in Bactrian as compared to Dromedarian ($p < 0.05$), whereas MCV, leukocytes and neutrophils were towards higher side of normal range in Dromedary. Similarly, aspartate aminotransferase (AST), alanine aminotransferase (ALT) were also significantly high, whereas glucose and triglycerides levels were low in native Bactrian as compared to Dromedarian ($p < 0.05$). These findings suggested that there is species difference in adaptation parameters in response to high altitude. Further, native high lander Bactrian camel having better metabolic adaptation and non-glucose energy substrates dependent metabolism. These parameters could be useful for evaluating their health conditions and load carrying performance for further selection of elite animals as pack animals at high altitude.

Introduction

Camel is an even-toed ungulate under the genus *Camelus* that have characteristic fatty deposits known as "humps" at its back. The camels have been domesticated as livestock for milk, meat, fibre, transportation and racing. As working animals, they are uniquely suited for patrolling and load carrying in desert and hilly areas. There are three species of camel mainly single hump camel (*Camelus dromedarius*), double hump camel (*C. bactrianus*) and wild Bactrian camel (*C. ferus*). Single hump camels are generally known as Dromedarian or Arabian camel. Dromedarian are usually found in the Horn of Africa, Middle East and South Asia, while double humped camels are generally known as Bactrian and found in Central Asia (Wu et al., 2014). The wild Bactrian camel are now critically endangered. They can adapt easily in hot desert and harsh conditions due to their ability to remain without drinking water for extremely long periods and having fluctuating body temperature.

In India, Bactrian are generally found in the cold desert region of Nubra Valley, Partapur where temperature ranges from + 30°C to -40°C, while Dromedarian are found in the Rajasthan and Gujarat state (Rosati et al., 2005). The total population of Bactrian and Dromedarian camels in India is around 210 and 2,45,000, respectively. The camels can work comfortably in the extremes of altitude and temperature. The camels are known for their distinctive ability to travel on hilly rough areas, and can carry weight up to 200 to 250 kg. On the other hand, pack animals such as mules and ponies can carry only limited quantities of 60 to 70 Kg

load (Vivek et al., 2018). However, an in-depth study is further needed for understanding their physiology, and adaptation mechanism for their use as pack animals at high altitude.

The trans Himalayan high altitude region of India is characterized by low atmospheric pressure, extreme temperature variation of -35°C to 40°C, low humidity, high UV-radiation and low partial pressure of oxygen. All these adverse climatic conditions leads to oxidative stress, impaired immune system, poor growth and reproductive health in livestock at high altitude (Kumar et al., 2019). The most important stress factor at high altitude is hypobaric hypoxia which is considered as a severe physiological stress factor. It could affect physiological, serum biochemical and haematological parameters which are important indicator of the animals' health status. However, camels have some unique adaptability to these stress conditions as depicted by their reproductive behaviour, load carrying capacity, exercise endurance and disease resistance in spite of poor nutrition at high altitude (Zongping, 2003; Omid et al., 2014; Dahiya et al., 2014). Hence, local farmers are more dependent on camels in such areas for load carrying and logistics purpose. These camels have also gained significant attention by Indian army personnel for their use as pack or saddle animals at high altitude. However, there is need to investigate the mechanism of adaptation in detail in both the camels breeds in response to stress conditions. More comprehensive studies are required at the moment to understand their physiology at high altitude stress conditions.

Various researchers have conducted work on camel physiology and hematology, and also studied the effect of season, age, sex on haematological and biochemical parameters in Saudi-Arabia, Sudan, India and Iran in hot desert region (Al-Busadah and Osman, 2000; Babeker et al., 2013; Deen, 2013; Gattani et al., 2017). However, no knowledge is available on camel morphological, haematological, physiological and serum biochemical adaptation parameters in cold desert high altitude region. The analysis of blood components can also help the clinician for easy evaluation of the health status of animals. So far no studies have been done on the analysis of these physio-biochemical parameters to evaluate their feasibility for load carrying and patrolling in high altitude region, which can be helpful in selection of elite breeds from different regions. Therefore, the main aim of this study was to evaluate the effect of high altitude on physiological and biochemical parameters in low lander Dromedarian and native high lander Bactrian camel. Findings of this study could be helpful in diagnosis of disease and in examination of the endurance level of camels for logistic use in Ladakh region. This study will also be helpful in establishing a base line of reference values for physiological, biochemical and haematological parameters in normal and healthy camels at high altitude to highlight the effect of altitude.

Material And Methods

Compliance with ethical standards

All experimental camels were obtained from Pack animal section, Animal Science Division, DRDO-Defence institute oh High Altitude Research, Leh-Ladakh, India. The necessary permission was obtained from Institute animal ethics committee for the experiments. All field operations and animal experiments were performed as per the regulations of the institute animal ethics committee of the DIHAR, C/o 56 APO, Leh-Ladakh.

Animals and sampling procedure

This study was conducted at Defence Institute of High Altitude Research (DIHAR), Leh-Ladakh which is located at 3500 meter mean sea level (msl). Total four low lander Dromedarian and four native high lander Bactrian camels were selected for sampling. The Dromedarian camels were introduced for research in high altitude region from Rajasthan, and they were slowly moved in stages from Bikaner to Kashmir to Ladakh. All the camels were normal and healthy during the sampling period. Total 10 ml of blood sample was collected from the jugular vein in morning for separation of serum and analysis of different parameters.

Determination of morphological and physiological parameters

All morphological parameters were recorded as described by Yosef et al. (2014) using metal measurement tape. The thickness of shank and abdomen skin were measured using stainless steel Vernier Caliper (MGW Precision VCF200). The physiological parameters such as pulse rate and respiration rate were recorded by Stethoscope and by manually counting breaths per minutes through nasal orifice, respectively. The temperature were recorded by Laser Digital Infrared Thermometer.

Determination of hematological parameters

Hemoglobin concentration was estimated by Sahli's method (Van Kampen and Zijlstra, 1961). Packed-cell volume (PCV) was determined by Hematocrit capillary tube method (Schalm et al., 1975). Red blood cells (RBC) and white blood cells (WBC) were calculated by haemocytometer using phase contrast microscope (Schalm et al., 1975). The differential leukocyte count (DLC) was calculated by Giemsa stain method (Schalm et al., 1975). Erythrocyte sedimentation rate (ESR) was determined by Wintrobe tube Method (Jou et al., 2011). Platelets count was performed by sodium citrate dilution method (Ottenberg, & Rosenthal, 1917)

Determination of serum biochemical parameters

Serum glucose, total protein, albumin, calcium, creatinine, ALT, AST, uric acid, urea, triglycerides, iron and magnesium were estimated using serum biochemical analyzer (BS-120, Mindray Medical International Ltd.).

Determination of serum oxidative stress parameters:

The total antioxidant status in serum sample was estimated by Ferric Reducing Antioxidant Power (FRAP) assay as per Benzie and Strain (1996) method. However, free radical scavenging activity was measured by 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) radical scavenging assay as described by Blois (1958) and Abe et al. (2000). The radical scavenging activity was calculated as per following equation:

See equation 1 in the supplementary files.

where A_0 is the absorbance of the control (water instead of sample), and A_1 is the absorbance of the sample.

Statistical analysis

Results were expressed as means \pm standard error (SE) and analyzed statistically by independent t -test using SPSS statistical software (Version 24, IBM Corporation, USA). P -values less than 0.05 were considered statistically significant.

Results And Discussion

Morphological parameters

Among all the morphological parameters, body height, body length and neck length were significantly higher, whereas girth of shank was lower in low lander Dromedarian as compared to native high lander Bactrian camels ($p < 0.05$; Table 1). This variation in morphological parameters could be due their breed characteristics, as their body size is different in all the habitats. However, no significant variation was recorded in height of hump, distance b/w the eyes, girth of abdomen, and face length ($p > 0.05$). Interestingly, body height, body length, height of hump were within the normal range of Dromedary, but lies towards higher side. Moreover, hump girth, and skin thickness of abdomen and shank were significantly higher in low lander Dromedarian as compared to native Bactrian ($p < 0.05$). These are important morphological adaptation parameters which varies in cold and hypobaric hypoxia environment (Faye et al., 2001). The skin thickness and hump size are dependent on subcutaneous deposition of adipose tissue, which are primary source of non-glucose energy substrates in animals adapted to cold environment at high altitude (Faye et al., 2001; Kamili et al., 2006). Hence, these finding are indicative of morphological adaptation process of Dromedarian to cold oxidative stress conditions. However, high lander Bactrian camels have adapted very well in these conditions as indicated by lower girth of hump and skin thickness as compared to low lander camels. In the present study, these low lander Dromedarian camels were introduced to high altitude two years back. Hence, these Dromedarian camels were under the process of adaptation, and exhibited higher girth of hump, and skin thickness at shank and abdomen region. Various reports in literature have studied the morphological diversity in Ethiopian camels and Southern Moroccan camels to identify homogeneous groups depending on their body measurements (Higgins and Kock, 1984; Yosef et al., 2014; Boujenane et al., 2019). However, to the best of our knowledge there are no reports in literature on morphological parameters study of Bactrian camels. This is the first report on comparative study of all morphological parameters indicative of adaptation in low lander and native high lander camels to high altitude region. These morphological parameters and their reference ranges can also be helpful in the evaluation of overall growth of animal for further selection of elite breeds for logistic purpose e.g. endurance exercise, load carrying and patrolling.

Physiological parameters

Among all the physiological parameters, heart rate was significantly high, whereas the rectal temperature was low in Dromedarian camels than the Bactrian camels ($p < 0.05$; Table 1). The heart rate and rectal temperature were within the normal reference range in native Bactrian camels. However, low lander Dromedarian camels showed very high heart rate which lies beyond the reference range of camel. This parameter at higher level is an indicative of adaptation changes in Dromedarian camels. High altitude stress conditions induces hormonal and neuronal changes in body by increasing the sympathetic nervous system activity (Simmonyi, 2014). This leads to a significant increase in blood pressure and heart rate in Dromedarian camels at high altitude. Interestingly, the rectal temperature was lower than the normal reference range in Dromedarian camels, which is indicative of poor energy metabolism. The body homeostasis is an important indicator of physiological status of animal adaptation to particular environment (Mohammed et al., 2007). However, both these parameters were within the normal range in Bactrian camel. These findings revealed that Bactrian camels are more adapted to these extreme conditions than the low lander Dromedarian camels even after two years of rearing of low lander at high altitude. The body temperature and heart rate are dependent on body metabolism and animal response to stress. Therefore, heart rate and rectal temperature of Dromedarian camel indicates these animals are having poor metabolism and adaptation response to stress prevalent at high altitude. Similar observations have been recorded in earlier reports on camels (Higgins and Kock, 1984; Al-Haidary et al., 2016).

Hematological parameters

Among all hematological parameters, platelets, ESR and lymphocytes levels were significantly high in native high lander Bactrian camels ($p < 0.05$; Table 2). However, total leukocytes and neutrophils count were higher in low lander Dromedarian as compared to Bactrian camels ($p < 0.05$). There was no significant variation in hemoglobin (Hb), PCV, erythrocytes, monocytes, eosinophil, basophils, MCV, MCH and MCHC levels between the two breeds of camels ($P > 0.05$). The erythrocyte size of Dromedarian camel was significantly higher than the Bactrian camel ($p < 0.05$; Table 2 and Fig 1, 2). Blood Hb concentration and erythrocytes count were almost similar and within the range in both the breeds.

Despite similar erythrocyte count and Hb levels, MCV (mean corpuscular volume) values in Dromedarian camels were greater than the Bactrian and normal reference range reported in literature (Table 2). This may be due to large size of immature erythrocytes which are also known as reticulocytes (Fig 2). The reticulocytes are capable of more cellular oxygen transport due to their high affinity to oxygen. The low lander Dromedarian camel rearing at high altitude need more efficient cellular oxygen transport system to adapt under hypobaric-hypoxia conditions of high altitude (Adili et al., 2013). The microscopic size measurements also revealed larger size of erythrocytes in Dromedarian camel (Fig. 2). The large size of erythrocytes are indicative that low lander camels are under the process of haematological adaptation to hypobaric hypoxia prevalent at high altitude (Banerjee et al., 1962).

The total leukocytes count was significantly high in low lander Dromedarian as compared to native Bactrian camels. Increase in leukocytes count could be due to compromised immune system under stressful conditions (Su et al., 2018). More leukocytes are required to cope up with these severe environmental stress condition in order to survive. Therefore, this increase in leukocytes count could be due

to stress factors prevalent at high altitude hypoxia conditions, which triggers immune response for homeostasis maintenance (Ouajd and Kamel, 2009). However, low leukocytes count in Bactrian camel along with higher lymphocytes counts are indicative of better adaptation response to high altitude.

The morphological changes in neutrophils in the form of band shaped and segmented neutrophils were observed in both the breeds of camels (Fig. 1 and 2). However, these morphological changes and neutrophils number were significantly high in Dromedarian camels as compared to Bactrian camels (Table 2), whereas the number of lymphocytes were high in native Bactrian camels. These findings are indicative of free radicals generation and immunosuppression under high altitude stress conditions. (Zongping, 2003; Ouajd and Kamel, 2009). Various studies observed that more neutrophils are released to counter oxidative stress-induced free radicals and microbial infections (Higgins and Kock, 1984). Moreover, neutrophils number increases in acute response to stress conditions, whereas lymphocytes number increases in chronic response conditions (Klokke et al., 1993). This indicates that low lander camels are under the process of adaptation in response to high altitude, while high lander camels have adapted very well in these conditions resulting in lower neutrophils and higher lymphocytes count. Since, these high lander Bactrian camels are bred and reared for several generations under high altitude stress conditions, all these changes are likely to be acquired by them in response to high altitude conditions over several generations.

In the present study, the level of platelets were significantly high in both the breeds of camels, which could be due to stimulation of platelets precursors cells in response to hypoxia conditions at high altitude (Table 2). There is competitive response between stem cells of erythrocyte and platelets precursor cells. Hence, increase in platelets number is an indicative of adaptation changes to hypobaric hypoxia. The normal hematological findings reported here will be useful in the studies of clinical conditions of the camel at high altitude region. Several investigators have studied the hematological parameters and their reference ranges in camels in hot desert regions for clinical interpretation of data (Banerjee et al., 1962; Farooq et al., 2011; Elitok and Cirak, 2018; Islam et al., 2019). However, detailed studies of hematological parameters at high altitude region have not been carried out so far.

Biochemical and oxidative stress parameters

The biochemical parameters showed significantly higher level of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and creatinine, whereas significant decrease in glucose and triglycerides levels in native Bactrian as compared to Dromedarian camels ($p < 0.05$; Table 3). However, other parameters viz. albumin, total protein (TP), calcium, magnesium, uric acid and iron remain unaffected (Table 3). The high AST and ALT levels in Bactrian indicates that the liver metabolism is highly active under stress at high altitude region which releases more ALT and AST level into the blood during adaptation (Aragon & Younossi, 2010). Slightly higher creatinine and urea level in native Bactrian camels indicates more active renal metabolism, which might be a adaptive mechanism of water conservation in high altitude cold stress conditions (Samra & Abcar, 2012). Liver metabolism is a vital physiological process to maintain body homeostasis to fulfill cellular function under stressful conditions. The animal susceptible to environmental stress conditions have poor metabolism, and therefore their body temperature is lower than the normal, and they are more prone to stress mediated ailments. In present study, low lander camel has significantly low

rectal temperature than the Bactrian camels and normal reference values, which is an indicative of poor liver metabolism at high altitude. Hence, our findings supported the hypothesis of higher liver and kidney metabolic activity required for metabolic adaptation to high altitude.

Interestingly, total serum glucose levels recorded in native Bactrian camels were very low as compared to Dromedarian camels (Table 3). Earlier reports have documented that exposure to high altitude region leads to transient increase in glycemic index initially, this could be an adaptive mechanism to low energy level which is effective in camel at high altitude (Brooks et al., 1991; Larsen et al., 1997). However, prolonged and continuous exposure to high altitude lowers glycemia in serum (Brooks et al., 1991). The acclimatization to high altitude seems to be the main reason for the increase ATP fuel dependency from non-glucose energy sources. Under cold stress, non-glucose energy substrates are more important and generally preferred for ATP generation. At high altitude, the glucose based energy diets are avoided and protein-fat based diets are preferred as adaptation mechanism for cellular energy generation. In present study, low glucose level were observed in native Bactrian, which is an indicative that native Bactrian camels are more dependent on non-glucose energy substrates. Whereas, high triglycerides and glucose levels were present in low lander camels, which shows that the energy metabolism in Dromedarian is more dependent on glucose and triglycerides rather than protein-fat diet. This further support the hypothesis that low lander camels are poorly metabolically adapted to high altitude conditions. All these important findings indicated the effect of climate on biochemical parameters, which is an important indicator of metabolic adaptation behavior in camel at high altitude (Omidi et al., 2015; Elitok & Cirak, 2018; Islam et al., 2019).

The present study observed no significant difference in oxidative stress markers, DPPH, and FRAP between low lander and high lander camels from different origins (Table 3). The high antioxidant levels help in reducing oxidative stress generated cellular damage in camels induced by high-altitude adverse conditions (Kumar et al., 2019). Hence, the oxidative stress reducing ability to protect important biomolecules like DNA, RNA, proteins, carbohydrates and lipids in their functional active state was very well documented in camels serum samples. These results suggests the importance of estimation of antioxidant parameters for monitoring health status and endurance parameters. In conclusion, the current study helped in understanding of morphological, haematological and physio-biochemical adaptation mechanism in camels to high altitude environment. These variations could be due to diversity in genetic makeup, environmental factors and altitude effect.

Conclusion

The present study concluded that the native high lander Bactrian camel has effective liver metabolism, and more dependency on non-glucose energy sources as compared to low lander Dromedarian camel. The change in leukocytes number and neutrophils morphology was observed to counter environmental stress conditions prevalent at high altitude. Further, this study revealed that variation in physio-biochemical and haematological parameters in two breeds of camel is an indicative of difference in stage of adaptation to high altitude. However, further studies are required to demonstrate changes in these physio-biochemical and haematological long term adaptation parameters, which will be helpful in selection of well adapted breed to high altitude stress conditions for endurance performance.

Declarations

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Authors' contributions

GG, SK and DL performed all the experiments related to biochemical, haematological and physiological analysis. PR helped in animal sampling and carried out experiments on morphological parameters characterization. GG and VKB drafted the main manuscript. VKB conceived, designed, and coordinated the complete study. OPC supervised the whole study. All authors read and approved the manuscript.

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Tables

Table 1: Mean (\pm SEM) and ranges of physiological and morphological parameters in camels at high altitude.

S. N.	Physiological Parameters	Dromedarian Camels	Bactrian Camels	Reference range for Dromedary [#]	Reference range for Bactrian [#]
1	Heart rate (bpm)	44.25 \pm 0.85*	34.5 \pm 0.95*	28.0 - 33.0	
2	Respiration Rate (bpm)	13.0 \pm 0.94	12.0 \pm 0.81	5.0 - 12.0	
3	Rectal Temperature ($^{\circ}$ C)	26.5 \pm 1.84*	32.25 \pm 1.37*	34 - 39	
Morphological parameters					
1	Height at withers (inches)	80.00 \pm 2.34*	66.38 \pm 0.68*	72.54 - 81.01	59.80 - 70.0
2	Body Length (inches)	65.00 \pm 1.78*	55.63 \pm 1.49*	61.41 - 63.46	51.00 - 60.00
3	Height of hump (inches)	13.50 \pm 1.48	11.50 \pm 0.79	8.54 - 14.82	10.51 - 12.00
4	Girth of hump (inches)	46.75 \pm 3.54*	34.00 \pm 1.09*	34.64 - 60.23	30.90 - 45.74
5	Thickness of abdomen skin (cm)	1.67 \pm 0.13*	1.11 \pm 0.07*	-	-
6	Girth of abdomen (inches)	83.13 \pm 0.77	81.38 \pm 1.52	79.72 - 89.66	-
7	Circumference of shank (inches)	29.88 \pm 0.82*	37.13 \pm 0.52*	-	-
8	Thickness of shank skin (cm)	1.30 \pm 0.11*	0.86 \pm 0.04*	-	-
9	Neck length (inches)	37.25 \pm 0.85*	31.75 \pm 1.10*	36.60 - 48.03	35.90 - 40.00
10	Face length (inches)	19.10 \pm 0.44	19.13 \pm 0.65	17.78 - 23.98	15.90 - 20.00
11	Distance b/w eyes (inches)	9.80 \pm 0.12	9.75 \pm 0.43	8.37 - 10.02	8.20 - 9.01
12	Back hump height (inches)	-	11.30 \pm 0.79	-	14.90 - 17.70
13.	Back hump girth (inches)	-	33.25 \pm 1.93	-	-

Reference range - Yosef et al.(2014) Makhdoomi et al. (2013); *Significant variation ($p<0.05$); bpm-beats per minute; SEM-Standard error mean

Table 2: Mean (\pm SEM) and ranges of haematological parameters in camels at high altitude.

S. No.	Haematological parameters	Dromedarian Camels	Bactrian Camels	Reference range for Dromedary [#]	Reference range for Bactrian [#]
1	Hemoglobin (g/dl)	13.47 \pm 0.51	13.45 \pm 0.52	11.0 - 14.5	11.0 - 17.0
2	ESR value (mm/hr)	0.48 \pm 0.08*	0.88 \pm 0.07*	0.0 - 1.0	0.0 - 1.0
3	Packed cell volume (%)	39.25 \pm 1.43	36.75 \pm 2.32	24.0 - 42.0	25.00 - 39.0
4	RBC's ($\times 10^6 / \text{mm}^3$)	6.95 \pm 0.52	7.0 \pm 0.39	4.3 - 12.4	8.5 - 19.0
5	RBC's size (LxB) (μ)	7.37 \pm 0.2 x 4.53 \pm 0.1*	5.81 \pm 0.11 x 3.54 \pm 0.08*	-	-
6	MCV (fl)	57.06 \pm 3.02	52.93 \pm 4.22	27.5 - 29.4	25.3 - 31.6
7	MCH (pg)	19.76 \pm 1.78	19.28 \pm 0.47	11 - 35	7 - 35
8	MCHC (g/dl)	34.53 \pm 2.21	36.99 \pm 2.44	22 - 46	27 - 42
9	WBC's ($\times 10^3 / \text{mm}^3$)	16.8 \pm 1.01*	10.0 \pm 0.77*	4.0 - 22.3	8.6 - 16.5
10	Platelets ($\times 10^5 / \text{ul}$)	5.36 \pm 0.26*	6.4 \pm 0.30*	2.3 - 3.6	2.2 - 5.26
11	Neutrophils (%)	71.00 \pm 2.17*	60.25 \pm 1.93*	33.0 - 70.0	55.0 - 79.0
12	Banded neutrophils (%)	22.39 \pm 1.73	23.82 \pm 1.21	-	-
13	Segmented neutrophils (%)	20.06 \pm 2.59	16.51 \pm 0.45	-	-
14	Lymphocytes (%)	26.00 \pm 1.93*	36.50 \pm 2.39*	21.0 - 62.0	18.0 - 33.0
15	Monocytes (%)	2.00 \pm 0.0	1.75 \pm 0.25	0.0 - 7.0	0.0 - 4.0
16	Eosinophils (%)	1.00 \pm 0.0	1.50 \pm 0.28	0.0 - 4.0	0.0 - 9.0
17	Basophils (%)	Nil	Nil	0-1.00	0-1.00

Reference range adapted from- Elitok and Cirak, (2018); Farooq et al. (2011); Banerjee et al. (1962); *Significant variation between two breeds ($p<0.05$); MCV - Mean Corpuscular

Volume; MCH- Mean Corpuscular Hemoglobin; MCHC- Mean Corpuscular Hemoglobin Concentration.

Table 3: Mean (\pm SEM) and ranges of biochemical and antioxidant parameters in camels at high altitude.

S. No.	Biochemical parameters	Dromedarian Camels	Bactrian Camels	Reference range for Dromedary [#]	Reference range for Bactrian [#]
1	Total Protein (g/dl)	7.31 \pm 0.123	7.49 \pm 0.137	6.3 - 8.7	5.5 - 7.0
2	Albumin (g/dl)	4.10 \pm 0.08	4.05 \pm 0.12	3.0 - 4.4	2.8 - 3.3
3	Glucose (mg/dl)	94.43 \pm 9.1*	50.67 \pm 3.8*	26.0 - 240.0	nm
4	Alanine aminotransferase (U/L)	10.33 \pm 0.86*	20.28 \pm 1.25*	10.0 - 25.0	
5	Aspartate aminotransferase (U/L)	80.55 \pm 1.5*	122.90 \pm 14.16*	30.0 - 57.0	69.0 - 98.0
6	Triglycerides (mg/dl)	52.57 \pm 3.02*	41.42 \pm 3.23*	8.4 - 82.22	nm
7	Urea (mg/dl)	48.16 \pm 2.52	52.74 \pm 4.31	15.6 - 48.34	15.5 - 61.26
8	Creatinine (mg/dl)	2.72 \pm 0.15*	4.02 \pm 0.49*	1.2 - 2.8	0.85 - 2.5
9	Calcium (mg/dl)	9.99 \pm 0.18	10.08 \pm 0.23	6.3 - 11.0	6.4 - 10.3
10	Iron (mg/L)	1.48 \pm 0.14	1.30 \pm 0.13	1.2 - 3.49	0.83 - 1.5
11	Magnesium (mg/dl)	2.90 \pm 0.12	2.80 \pm 0.13	1.8 - 2.9	1.8 - 2.3
	Antioxidant parameters			Dromedary[‡]	Bactrian[‡]
1.	DPPH scavenging activity (%)	41.23 \pm 2.9	38.36 \pm 4.32	27.24 - 55.3	27.40 - 38.65
2.	FRAP assay (μ mol/L)	241.75 \pm 32.05	238.75 \pm 17.93	210.0 - 280.00	225.0 - 264.00
3.	Uric acid (mg/dl)	0.52 \pm 0.32	0.10 \pm 0.00	0.3 - 0.7	

[‡] Reference range adapted from - Bogin, (2000); Elitok and Cirak, (2018); Abdalmula et al. (2018); [‡] Reference range calculated from present study; *Significant variation between two reeds (p<0.05)

Figures

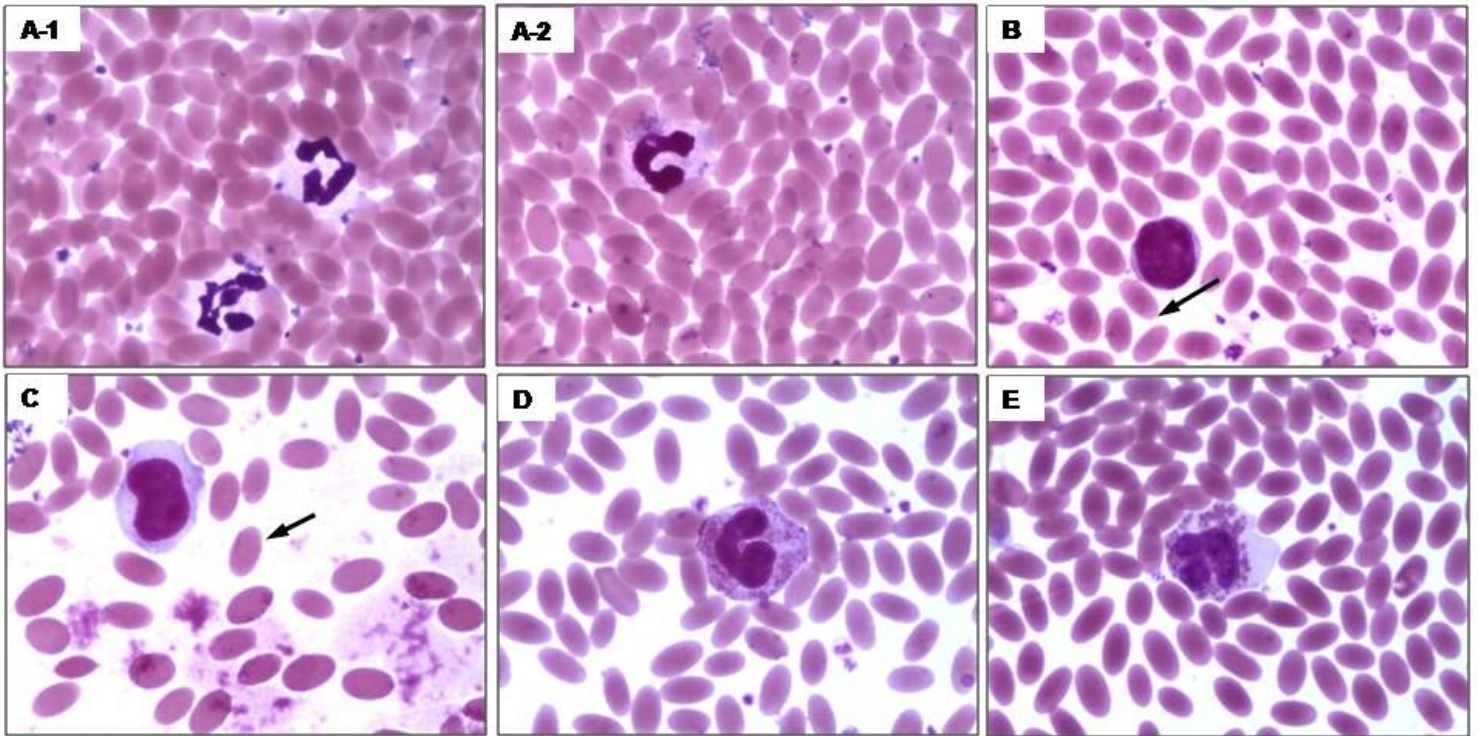


Figure 1

Morphology of different types of leukocytes, A-1) Segmented neutrophils; A-2) Banded or horseshoe shaped neutrophils; B) Mature lymphocytes; C) Monocytes; D) Eosinophils; E) Basophils; along with oval and elliptical shaped erythrocytes having size of $5.81 \times 3.54 \mu\text{m}$ (arrow sign) in high lander native Bactrian camels (Wright-Giemsa; Original magnification 1000 x).

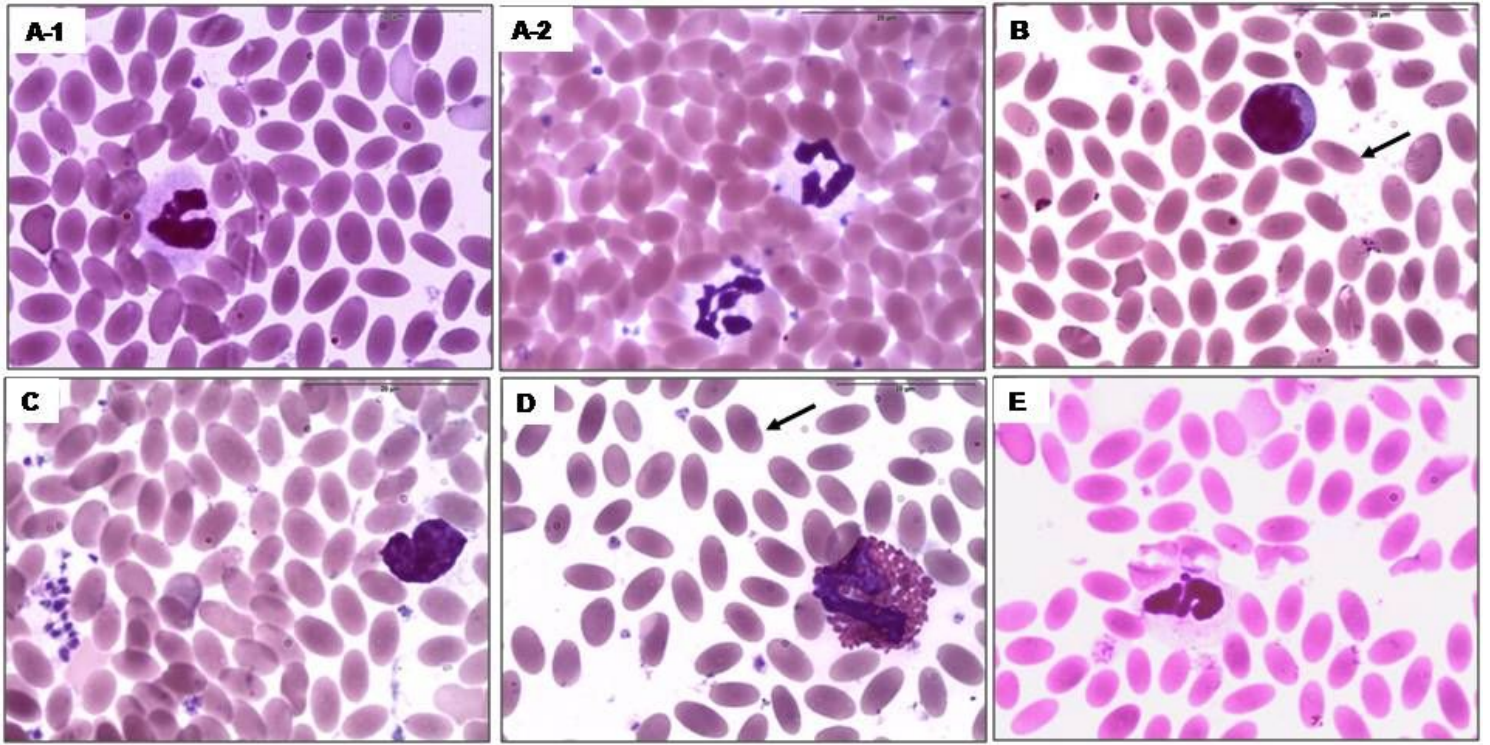


Figure 2

Morphological characteristics of different types of leukocytes, A-1) Banded or horseshoe shaped neutrophils; A-2) Segmented neutrophils; B) Mature lymphocytes; C) Monocytes; D) Eosinophils; E) Basophils; along with oval and elliptical shaped erythrocytes having size of $7.37 \times 4.53 \mu\text{m}$ (arrow sign) in low lander Dromedarian camels (Wright-Giemsa; Original magnification 1000 x).

Supplementary Files

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- [equation.docx](#)