Saudi Journal of Biological Sciences 30 (2023) 103677

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Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Haematological and biochemical blood reference values for Canary Island camels (*Camelus dromedarius*), an endangered dromedary species

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ARTICLE INFO

Article history:
Received 5 March 2023
Revised 11 April 2023
Accepted 27 April 2023
Available online 4 May 2023

Keywords:
Dromedary camel
Haematology
Clinical biochemistry
Reference values
Canary Islands

ABSTRACT

The purpose of this research was to develop reference values for haematological and biochemical variables in the Canary camel breed (*Camelus dromedarius*). 114 clinically healthy dromedary camels were assessed. Age, sex, and pregnancy status was also recorded. The reference range for red blood cells (RBCs) was 8.45 – 13.65 $X10^6$/μL, haemoglobin (HGB) was 10.61 – 15.29 g/dL, packed cell volume (PCV) was 19.93 – 32.51 %, and white blood cells (WBCs) 7.35 – 18.36 $X10^3$/μL. A correlation was established between the haemoglobin concentration (HGB) (g/dl) and packed cell volume (PCV) obtaining a linear regression (HGB = 0.31 PCV + 4.67). Young animals had higher RBC and WBC values than adult animals. Additionally, blood urea nitrogen (BUN), phosphorus, calcium, albumin/globulin (A/G) ratio, alkaline phosphatase, cholesterol, and lipase were higher in young animals compared with adults. Female dromedary camels showed higher values for the three main variables: RBC, HGB and PCV, but no differences between sexes were detected in the biochemical variables results. The WBC count was higher in non-pregnant females than in pregnant animals. These results provide references values for the Canary camel breed and may contribute to the understanding of differences in 18 haematological and biochemical parameters in dromedary camels with a potential impact in health and welfare for this species.

1. Introduction

Approximately 600 years ago, the introduction of Dromedary camels (*Camelus dromedarius*) to the Canary Islands led to their traditional use for agricultural purposes (Schulz, 2008). However, agriculture is currently a minor contributor of the economy of the islands, with the majority of income coming from tourism (Canary Islands Government, 2023). This species has become a symbol of Canarian tourism due to its popularity for camel rides (Wilson and Gutierrez, 2015).

The Canarian Camel underwent an exhaustive and rigorous study to complete its morphological, genetic, demographic and ethnographic characterization (Schulz et al., 2010). The results of these studies led the National Coordination Commission for the Conservation, Improvement and Promotion of Livestock Breeds to recognize the Canary Island Camel as a breed in 2012, thus making it the only European native breed of its kind (ARCA, 2023). Subsequently, the Canarian Camelid breed was declared endangered by

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2023.103677
1319-562X/

the Ministry of Agriculture via Order APM/26/2018, dated 11 January 2018 (Royal Decree 45/2919 of 8 January 2019).

Several studies has been conducted on the haematological, biochemical and trace element parameters in the blood of dromedaries (Aichouni et al., 2010; Elitok and Cirak, 2018; Faye and Bengoumi, 2018; Geffré et al., 2009). The results of these studies are likely to be biased by various physiological factors, such as age (Al-Busadah and Osman, 2000; Saeed and Hussein, 2008), sex and reproduction status (Al-Busadah and Osman, 2000; Al-Harbi, 2012; Ebissy et al., 2019; Faraz et al., 2021, 2020; Ibrahim et al., 2017; Jalali et al., 2018; Joshi et al., 2017; Ragab Hassan Mohamed et al., 2021; Saeed et al., 2011; Zaher et al., 2017), diet and/or geoclimatic conditions (Abdoslam et al., 2018; Amin et al., 2007; Elhag Eltahir et al., 2016; Farooq et al., 2011; Faye and Bengoumi, 2018; Islam et al., 2019; Lamo et al., 2020; Mohamed and Hussein, 1999; Waziri et al., 2019), breed and genetic variation (Abdalla et al., 1988; Abdussamad et al., 2015; Aichouni et al., 2010; AL-Busadah, 2007; Elhag Eltahir et al., 2016; Narnaware et al., 2016; Osman and., 2003), livestock or animal husbandry characteristics of each country or region (Elitok and Cirak, 2018; Faraz et al., 2021, 2018; Mohamed and Hussein, 1999), exercise and load carrying (Adah et al., 2017; Auer et al., 2015; Elhag Eltahir et al., 2016).

The impact of the sampling and laboratory method used has been described in the literature (Al-Busadah and Osman, 2000). The camel is an adaptable species (AL-Busadah, 2007; Viesselmann et al., 2019); thus, the published data cannot be extrapolated to the general population due to different environmental conditions. Additionally, many previous studies used a low number of animals to available published reference values and thus they would not be applicable in other nations with different geoclimatic conditions and or/variety of breeds. This phenomenon is comparable to what is seen in the majority of ruminants (Faye and Bengoumi, 2018).

The determination of haematological parameters is beneficial to determine the health status of animals (Faye and Bengoumi, 2018). Anaemia, which is a common ailment among dromedaries, could be detected using blood reference ranges (Alsaad, 2021; Ismail-Hamdi et al., 2022). Studies have described changes in blood variables associated with various diseases or clinical conditions (Egbe-Nwiyi et al., 2016; Faye and Bengoumi, 2018; Mohamed et al., 1984) or in response to different drugs such as xylazine or ketamine (Azari et al., 2012; Singh et al., 2007).

To our knowledge, there are no published data on haematological and biochemical reference values for *Camelus dromedarius*, the Canarian camel breed. Therefore, the current study aimed to provide a baseline of haematological and biochemical parameters which can be used to assess the health and welfare of Canarian camels in farms or zoos, and initiate appropriate therapeutic measures, if needed. The literature has widely discussed variations in haematological and biochemical reference values in camelids (Faye and Bengoumi, 2018); however, our results may provide insight into these variations in the Canary dromedary camel. Reference values for this breed was calculated using the methodology described in the literature (Friedrichs et al., 2012; Geffré et al., 2009).

2. Material and methods

The present study was conducted at the Veterinary Teaching Hospital of the Faculty of Veterinary Medicine, University of Las Palmas de Gran Canaria (ULPGC), in accordance with the research line pertaining to Dromedary Medicine. The procedure was revised by the Ethics Committee for Animal Experimentation of ULPGC (OEBA-ULPGC – 12/2023). The animals used were housed in two farms located on the island of Fuerteventura (Canary Islands, Spain), and belonged to a zoological park (Oasis Wildlife Park Fuerteventura). The animals were located in the Canary Islands and belonged to the same farmer but were kept in two farms located 40 km apart, one for milking purposes (28°27′22.2″N 13°53′57.4″W) and the other is a zoo (28°11′12.9″N 14°9′48.3″W).

2.1. Animals

Clinically healthy dromedary camels (*Camelus dromedarius*) (N = 114) were used in this study. The animals were examined individually in the handling chute available on the farm. The animals were distributed in 23 males and 91 females (with 20 pregnant camels). All animals were identified by microchip and their birth date was recorded. For the purpose of this study, animals younger than one year were considered young (n = 25), and those older than four years old were considered adults (n = 89), a criteria which has been used previously (Saeed and Hussein, 2008; Waziri et al., 2019).

2.2. Blood sample collection

Venous blood samples were collected via jugular venipuncture using an 8 mL plastic polyethylene terephthalate (PET) vacuum tube containing of ethylenediamine tetra-acetic acid (EDTA) potassium salt as an anticoagulant agent (Vacutainer® BD® EDTA K2, Becton Dickinson, Madrid, Spain) and another 8 mL plastic PET vacuum tube with a serum separating polymer gel, but no anticoagulant (Vacutainer® BD® gel SST™ II, Becton Dickinson, Madrid, Spain). The samples were transported in ice packs to the laboratory. Blood without anticoagulant was centrifuged for 10 min at 3000 rpm, and the resulting sera were aliquoted, collected in sterile tubes, and stored at −80 °C until measurement of serum biochemical variables.

The climate in the Canary Islands is consistent year-round, thus the impact of the seasons was not taken into account in this study. Along the coasts, the daily average temperature ranges from 18 °C in January and February to 24/25 °C in July, August, and September. This study, which was part a non-experimental veterinary clinical practice, aimed to assess the health status of the animals, and thus the permission of the owner was sought for blood sampling in accordance with the National Regulations for Veterinary Professional Practice approved in 2015 by the General Council of Veterinary Associations in Spain as well as the internal protocols and good veterinary care practices of the Veterinary Teaching Hospital of the University of Las Palmas de Gran Canaria.

2.3. Determination of haematological values

The *ProCyte Dx Analyzer* ™ I(DEXX Laboratories, Inc., Westbrook, Maine, USA) with its associated calibration and software specifically tailored for haematological variables of camels was employed. The red blood cell variables included in this study were: red blood cell count (RBC), hematocrit (PCV), haemoglobin (HGB), mean cell volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), red blood cell distribution width (RDW), reticulocytes (RETIC; % and #), reticulocyte haemoglobin (RETIC-HGB) and nucleated red blood cells (nRBC; when presence suspected). Similarly, white blood cells variables were also evaluated, comprising of white blood cell count (WBC), neutrophils (NEU; % and #), lymphocytes (LYM; % and #), monocytes (MONO; % and #), eosinophils (EOS; % and #), basophils (BASO; % and #) and band neutrophils (BAND, when presence suspected). Platelet variables assessed included: platelet count (PLT), platelet distribution width (PDW), mean platelet volume (MPV) and plateletcrit (PCT).

The *Catalyst One Chemistry Analyser* ^{TM} (IDEXX Laboratories, Inc., Westbrook, Maine, USA) was used to measure the serum biochemical variables, which included creatinine (CREA) (mg/dL), Blood Urea Nitrogen (BUN) (mg/dL), BUN/CREA ratio, phosphorus (mg/dL), calcium (mg/dL), total proteins (g/dL), albumin (g/dL), globulin (g/dL), Albumin/Globulin (A/G) ratio, alanine aminotransferase (ALT) (IU/L), alkaline phosphatase (ALKP) (IU/L), Gamma-Glutamyl Transpeptidase (GGT) (IU/L), total bilirubin (TBIL) (mg/dl), cholesterol (CHOL) (mg/dl), te amylase (AMYL) (IU/L) and lipase (LIPA) (IU/L).

2.4. Reference values determination

Based on the statistical analysis and Gaussian data distribution, parametric with 90% CI of reference limits was employed for determination of reference values for the variable studied, according to the recommendation of Friedrichs et al., (2012).

2.5. Statistical analysis

Statistical analyses were conducted using SPSS v.27.0 (SPSS Inc. Chicago IL). Data obtained from the study were expressed as the mean ± standard deviation. The Kolmogorov–Smirnov test was applied to continuous variables to assess their normal (Gaussian) distribution. Differences in mean values between groups were evaluated using Student's T-test, and values of $P < 0.05$ were considered significant. Scatterplots were generated using Microsoft Excel (Microsoft 365, USA) to determine the association between haemoglobin concentration and haematocrit values. Linear regression models were obtained to investigate any correlation between measured haemoglobin and haematocrit values.

3. Results

The haematological and biochemical analyses results are detailed in Table 1. The reference range in dromedary camels for RBC was 8.45 – 13.65 $\times$ 10^6/μL, for HGB 10.61 – 15.29 g/dL and for PCV 19.93 –32.51 %, while the reference range for WBC was 7.35 – 18.36 $\times$ 10^3/μL. A statistically significant ($P < 0.05$) and a positive correlation (r = 0.742) between haemoglobin concentration and haematocrit was observed (Fig. 1). This can be expressed mathematically as haemoglobin concentration (g/dL) = 0.31 $\times$ PCV + 4.67. Table 2 shows the mean and standard deviation of the studied serum biochemical parameters, as well as the range of deviation.

Table 3 shows statistically differences between young and adult animals in most parameters studied, except for PCV, eosinophils, basophils, and mean platelet volume. Results indicated that young animals had higher RBC (12.35 ± 1.51 $\times$ 10^6/μL) than adult animals (10.06 ± 1.19 $\times$ 10^6/μL; $P = 0.001$) and higher leukocyte counts (16.14 ± 2.11 $\times$ 10^3/μL) than adult animals (11.19 ± 2.71 $\times$ 10^3/μL; $P = 0.001$). These differences were also observed in young animals exhibiting higher neutrophils, lymphocytes and monocytes counts compared to adults.

Statistically significant differences were observed between the serum biochemical parameters of young animals and adult animals. The young animals exhibited higher values for BUN, phosphorus, calcium, A/G ratio, alkaline phosphatase, cholesterol, and lipase. Conversely, the adult animals had higher values for creatinine, globulins and GGT. Conversely, there were no differences between the two groups for total proteins, albumin, ALT, TBIL or AMYL (Table 4).

Table 5 expresses the results of the comparing males and females, with only animals older than one year (N = 89) included to avoid vias due to growth. For the red blood series, females had statistically significant higher values for the parameters: RBC, HGB and PCV. In relation to the leucocyte series, the results were also statistically significant ($P = 0,017$), but the values were higher in males (12.84 ± 2.42 $\times$ 10^3/μL) than in females (10.83 ± 2.65 $\times$ 10^3/μL) in the leukocyte count. These differences were more pronounced in neutrophils than in the other types of leukocytes.

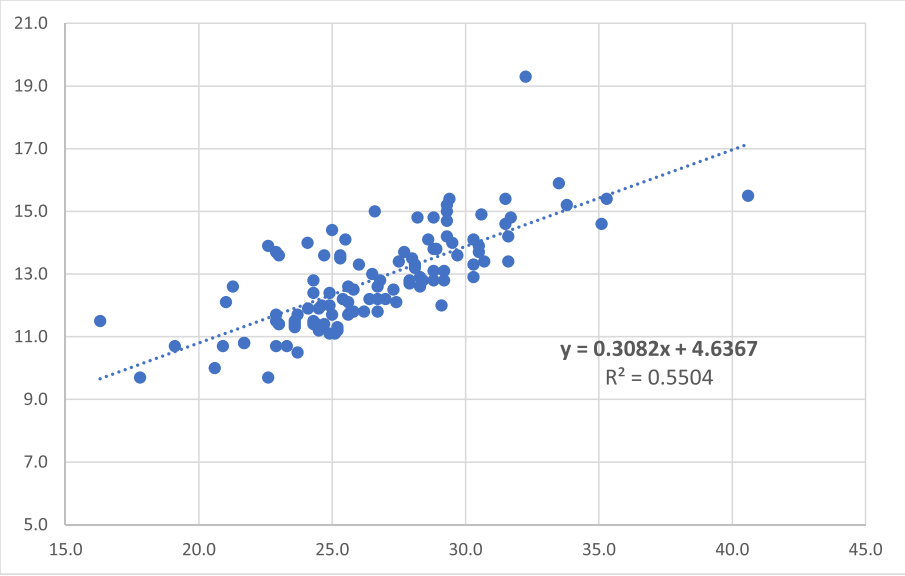
When assessing serum biochemical parameters between sexes, no statistically significant differences were observed. However, males exhibited higher phosphorus and globulin values and lower A/G ratio than females. Further information is provided in Table 6.

The comparison of haematological parameters between pregnant and non-pregnant females revealed no significant differences in most parameters; however, the white blood cell count was higher in non-pregnant females than in pregnant camels and the difference was significant for lymphocytes ($P = 0.011$). Serum bio-

Table 1
Mean ± standard deviation, minimum and maximum and percentiles (2.5, 50 and 97.5) of haematological variables of Canarian camel (*Camelus dromedarius*) (N = 114).

Parameters	Mean ± SD	Min	Max	5%	50%	95%
RBC (X10^6/μL)	10.56 ± 1.58	7.60	14.65	8.45	10.38	13.65
HBG (g/dL)	12.79 ± 1.58	8.60	19.30	10.61	12.75	15.29
PCV (%)	26.62 ± 3.70	16.30	40.60	19.93	26.30	32.51
MCV (fL)	25.23 ± 4.12	7.80	36.50	17.05	25.40	30.60
MCH (pg/cell)	12.20 ± 1.09	8.50	14.90	10.32	12.15	13.74
MCHC (g/dL)	48.59 ± 4.84	38.20	70.60	42.76	47.80	59.42
RDW (fL)	23.79 ± 2.25	19.50	30.90	20.40	23.40	28.08
RDW (%)	39.41 ± 3.04	26.20	45.10	36.41	39.60	44.05
RET (%)	0.14 ± 0.06	0.03	0.32	0.06	0.13	0.24
RET (X10^3/μL)	14.89 ± 7.37	2.60	36.40	5.15	13.50	30.46
RET-HBG (pg)	23.37 ± 6.42	12.20	44.90	14.82	22.00	36.25
WBC (X10^3/μL)	12.21 ± 3.20	5.37	18.86	7.35	11.70	18.36
NEU (X10^3/μL)	6.50 ± 1.91	2.88	12.62	3.78	6.14	10.39
LYM (X10^3/μL)	4.55 ± 1.84	1.39	9.65	2.19	4.57	7.90
MONO (X10^3/μL)	0.59 ± 0.27	0.06	1.66	0.31	0.52	1.09
EOS (X10^3/μL)	0.57 ± 0.33	0.09	2.60	0.19	0.52	1.04
BASO (X10^3/μL)	0.02 ± 0.03	0.00	0.25	0.00	0.01	0.07
PLT (X10^3/μL)	228.75 ± 96.62	56.00	517.0	129.1	194.5	454.5
PCT (%)	0.18 ± 0.08	0.06	0.45	0.09	0.15	0.33
MPV (fL)	7.73 ± 0.51	7.00	10.90	7.10	7.70	8.75

Note: Red blood cell (RBC), Packed Cells Volume (PCV), Haemoglobin (HGB), Mean cell volume (MCV), Mean corpuscular haemoglobin (MCH), Mean corpuscular haemoglobin concentration (MCHC), Red blood cell distribution width (RDW), Reticulocytes (RETIC) Reticulocyte haemoglobin (RETIC-HGB), White blood cell (WBC), Neutrophils (NEU) Lymphocytes (LYM), Monocytes (MONO), Eosinophils (EOS), Basophils (BASO), Platelet (PLT), Plateletcrit (PCT) and Mean platelet volume (MPV). SD = standard deviation, Min = minimum value, Max = maximum value, 5% = percentile 5, 50%= percentile 50, 95 = percentile 95.



N=114. y = determined haemoglobin concentration (g/dL). x = PCV **(%)**. R^2 = correlation coefficient.

Fig. 1. Scatterplots of the determined HGB concentrationversus PCV for all dromedary camels. ($r = 0.742$. $p < 0.05$). N = 114. y = determined haemoglobin concentration (g/dL). × = PCV **(%)**. R^2 = correlation coefficient.

Table 2
Mean ± standard deviation, minimum and maximum and percentiles (2.5, 50 and 97.5) of biochemical variables of Canarian camels (*Camelus dromedarius*) (N = 114).

Parameters	Mean ± SD	Min	Max	5%	50%	95%
CREA (mg/dL)	1.50 ± 0.36	0.70	2.60	0.90	1.50	2.10
BUN (mg/dL)	10.60 ± 6.08	2.00	25.00	4.00	8.00	23.00
BUN/CREA	8.41 ± 7.09	2.00	30.00	2.00	5.00	23.45
Phosphorus (mg/dL)	7.11 ± 2.27	4.50	13.50	4.83	6.20	11.96
Calcium (mg/dL)	8.95 ± 0.54	8.20	10.10	8.20	8.80	9.92
Total proteins (g/dL)	5.84 ± 0.56	4.50	7.50	5.00	5.80	7.00
Albumin (g/dL)	3.38 ± 0.47	2.30	5.00	2.70	3.40	4.25
Globulin (g/dL)	2.45 ± 0.28	1.90	3.60	2.00	2.40	2.95
A/G ratio	1.39 ± 0.25	1.00	2.30	1.00	1.40	1.84
ALT (IU/L)	30.93 ± 9.00	5.00	84.00	21.55	31.00	44.45
ALKP (IU/L)	198.98 ± 195.86	35.00	732.00	40.40	87.00	595.20
GGT (IU/L)	10.66 ± 5.85	0.00	56.00	4.00	10.00	16.65
TBIL (mg/dl)	0.26 ± 0.15	0.10	0.70	0.10	0.20	0.60
CHOL (mg/dl)	41.34 ± 28.60	7.00	120.00	8.55	33.00	105.75
AMYL (IU/L)	674.81 ± 247.86	337.00	1131.00	389.05	572.00	1099.00
LIPA (IU/L)	36.92 ± 21.02	11.00	82.00	12.00	31.50	79.20

Note: BUN = blood urea nitrogen. CREA = creatinine. A/G = albumin-globulin ratio. ALT = alanine aminotransferase. ALKP = alkaline phosphatase. GGT = gamma-glutamyl transpeptidase. TBIL = Total bilirubin. CHOL = cholesterol. AMYL = amylase. LIPA = lipase. SD = standard deviation. Min = minimum value. Max = maximum value. 5% = percentile 5. 50%= percentile 50. 95 = percentile 95.

chemical clinical parameters revealed lower levels in pregnant females than in non-pregnant females for BUN, BUN/CREA ratio and AMYL, and higher levels in pregnant females than in non-pregnant animals for Creatinine, Albumin, A/G ratio and cholesterol. Results are shown in Table 7 and 8.

4. Discussion

Our results from linear regression analysis indicated a similar relationship between HBG concentration and PCV values in dromedary camels, when comparing to those described for other species such as cattle (Turkson and Ganyo, 2015). This research suggests that a more accurate and suitable estimation of haemoglobin (HGB) concentration from Packed Cell Volume (PCV) in dromedary camels can be obtained. Furthermore, our findings are in agreement with those in human medicine, where the common conversion from packed cell volume (PCV) to haemoglobin (HGB) underestimates the prevalence of anaemia, as the result is multiplied by three, has been proposed (Carneiro et al., 2007; Khanam et al., 2013; Quintó et al., 2006; Rodríguez-Morales et al., 2007).

4.1. Geoclimatic factors

Our RBC counts results were within the high range of values previously reported for dromedary camels (Elitok and Cirak, 2018; Faye and Bengoumi, 2018), but outside the reference values. Compared to other species, dehydration in camels does not seem to have a significant effect on RBC counts (Mohamed et al., 1984). The wide variations reported in the literature have been attributed to geoclimatic factors (Faye and Bengoumi, 2018). Our results are comparable with those obtained in camels in Egypt, Iran, India, and South Africa, but higher than those observed in camels in Pak-

Table 3
Mean ± standard deviation of haematological variables of Canarian camels (*Camelus dromedarius*) (N = 114). For comparison between ages, animals older than 4 years of age were considered adults and calves were younger than 1 year of age.

Parameters	Calves (n = 25)	Adults (n = 89)	All (n = 114)	P-value*
RBC ($X10^6/\mu L$)	12.35 ± 1.51	10.06 ± 1.19	10.56 ± 1.58	**0.001**
HBG (g/dL)	13.59 ± 1.71	12.56 ± 1.48	12.79 ± 1.58	**0.004**
PCV (%)	25.47 ± 6.05	26.57 ± 3.65	26.62 ± 3.70	0.391
MCV (fL)	20.70 ± 5.00	26.50 ± 2.74	25.23 ± 4.12	**0.001**
MCH (pg)	11.04 ± 1.06	12.52 ± 0.85	12.20 ± 1.09	**0.001**
MCHC (g/dL)	56.50 ± 15.05	47.56 ± 3.83	48.59 ± 4.84	**0.001**
RDW (fL)	25.19 ± 2.55	23.40 ± 1.99	23.79 ± 2.25	**0.001**
RDW (%)	42.28 ± 1.96	38.60 ± 2.79	39.41 ± 3.04	**0.001**
RET ($X10^3/\mu L$)	24.45 ± 6.49	12.08 ± 4.83	0.14 ± 0.06	**0.001**
RET (%)	0.20 ± 0.05	0.12 ± 0.05	14.89 ± 7.37	**0.001**
RET-HBG (pg)	21.02 ± 5.20	24.06 ± 6.60	23.37 ± 6.42	**0.036**
WBC ($X10^3/\mu L$)	16.14 ± 2.11	11.19 ± 2.71	12.21 ± 3.20	**0.001**
NEU ($X10^3/\mu L$)	7.61 ± 1.50	6.18 ± 1.90	6.50 ± 1.91	**0.005**
LYM ($X10^3/\mu L$)	7.07 ± 1.48	3.90 ± 1.35	4.55 ± 1.84	**0.001**
MONO ($X10^3/\mu L$)	0.90 ± 0.28	0.50 ± 0.19	0.59 ± 0.27	**0.001**
EOS ($X10^3/\mu L$)	0.53 ± 0.29	0.58 ± 0.34	0.57 ± 0.33	0.443
BASO ($X10^3/\mu L$)	0.03 ± 0.05	0.02 ± 0.02	0.02 ± 0.03	0.097
PLT ($X10^3/\mu L$)	373.75 ± 82.29	187.81 ± 49.44	228.75 ± 96.62	**0.001**
PCT (%)	0.29 ± 0.07	0.14 ± 0.04	0.18 ± 0.08	**0.001**
MPV (fL)	7.78 ± 0.43	7.71 ± 0.53	7.73 ± 0.51	0.556

Note: Red blood cell (RBC). Packed Cells Volume (PCV). Haemoglobin (HGB). Mean cell volume (MCV). Mean corpuscular haemoglobin (MCH). Mean corpuscular haemoglobin concentration (MCHC). Red blood cell distribution width (RDW). Reticulocytes (RETIC) Reticulocyte haemoglobin (RETIC-HGB). White blood cell (WBC). Neutrophils (NEU) Lymphocytes (LYM). Monocytes (MONO). Eosinophils (EOS). Basophils (BASO). Platelet (PLT). Plateletcrit (PCT) and Mean platelet volume (MPV). * Statistically significant is highlighted. P-value for the Student T-test has been included.

Table 4
Mean ± standard deviation of biochemical variables of Canarian camels (*Camelus dromedarius*) (N = 114). For comparison between ages, animals older than 4 years of age were considered adults and calves were younger than 1 year of age.

Parameters*	Calves (n = 25)	Adults (n = 89)	All (n = 114)	P-value*
CREA (mg/dL)	1.06 ± 0.28	1.62 ± 0.28	1.50 ± 0.36	**0.001**
BUN (mg/dL)	19.36 ± 4.93	8.13 ± 3.60	10.60 ± 6.08	**0.001**
BUN/CREA	19.84 ± 6.05	5.20 ± 2.64	8.41 ± 7.09	**0.001**
Phosphorus (mg/dL)	10.55 ± 1.89	6.05 ± 0.93	7.11 ± 2.27	**0.001**
Calcium (mg/dL)	9.53 ± 0.23	8.56 ± 0.24	8.95 ± 0.54	**0.001**
Total proteins (g/dL)	5.74 ± 0.53	5.87 ± 0.57	5.84 ± 0.56	0.302
Albumin (g/dL)	3.45 ± 0.50	3.35 ± 0.47	3.38 ± 0.47	0.360
Globulin (g/dL)	2.28 ± 0.20	2.50 ± 0.27	2.45 ± 0.28	**0.001**
A/G ratio	1.52 ± 0.26	1.35 ± 0.23	1.39 ± 0.25	**0.002**
ALT (IU/L)	31.76 ± 4.29	30.70 ± 9.94	30.93 ± 9.00	0.604
ALKP (IU/L)	434.93 ± 122.40	62.85 ± 17.56	198.98 ± 195.86	**0.001**
GGT (IU/L)	7.56 ± 2.86	11.62 ± 6.21	10.66 ± 5.85	**0.002**
TBIL (mg/dl)	0.24 ± 0.16	0.27 ± 0.14	0.26 ± 0.15	0.436
CHOL (mg/dl)	58.79 ± 37.73	34.89 ± 21.36	41.34 ± 28.60	**0.001**
AMYL (IU/L)	741.20 ± 254.42	654.32 ± 243.74	674.81 ± 247.86	0.126
LIPA (IU/L)	50.64 ± 21.76	31.12 ± 17.95	36.92 ± 21.02	**0.001**

Note: BUN = blood urea nitrogen. CREA = creatinine. A/G = albumin-globulin ratio. ALT = alanine aminotransferase. ALKP = alkaline phosphatase. GGT = gamma-glutamyl transpeptidase. TBIL = Total bilirubin. CHOL = cholesterol. AMYL = amylase. LIPA = lipase. SD = standard deviation. Min = minimum value. Max = maximum value. * Statistically significant is highlighted. P-Value for the Student T test has been included.

istan, Sudan, Mauritania, Saudi Arabia, and other studies in camels in India reported (Faye & Bengoumi (2018) and Pakistan (Islam et al., 2019). The available evidence in the literature suggests that geoclimatic conditions may be a possible factor in the lower Red Blood Cells (RBC) counts, as these countries have wide deserts and possibly limited access to pasture (Amin et al., 2007). Poor quality feed intake during the dry season leads to significant changes in nutritional status and variations in RBC counts and other haematological indices (Amin et al., 2007).

The haemoglobin concentration of the dromedary camel was observed to vary statistically significantly between dehydration/rehydration status as described by Faye & Bengoumi (2018). In the current study, the animals had *ad libitum* access to water. The haemoglobin results obtained in the present study were similar to those reported in camels in Pakistan (Farooq et al., 2011) and Nigeria (Waziri et al., 2019) but subtly lower than those reported in camels in Kuwait (Mohamed and Hussein, 1999). Lower mean reference values were observed in camels in Bangladesh (Islam et al., 2019) and Sudan (Amin et al., 2007). However, all previously reported haemoglobin results were within the reference values used in the present study. The highest reference range has been attributed to the high altitude at which the *Camelus bactrianus* live, compared to animals living at low altitude (Lamo et al., 2020). Results reported in adult llamas were higher than those reported in camels (Vap and Bohn, 2015) and attributed to the differences related to methodology, husbandry, and environmental conditions.

Haematocrit values vary significantly between studies, with results showing no variation in haematocrit during the first week of dehydration in the dromedary camel (Faye and Bengoumi, 2018). In comparison to other studies, our mean haematocrit was similar to that reported in camels in Nigeria (Waziri et al., 2019) and lower than those reported in camels in Kuwait (Mohamed and Hussein, 1999). However, our reference range was shorter than those reported both in Nigeria (Waziri et al., 2019) and in racing

Table 5
Mean ± standard deviation of haematological variables of Canarian camels (*Camelus dromedarius*) (N = 89). For comparison between sexes only animals older than 1 year have been included.

Parameters	Males (n = 16)	Females (n = 73)	Adults (n = 89)	P-value*
RBC ($X10^6/\mu L$)	9.00 ± 0.58	10.29 ± 1.16	10.06 ± 1.19	**0.001**
HBG (g/dL)	11.86 ± 0.89	12.72 ± 1.54	12.56 ± 1.48	**0.033**
PCV (%)	24.24 ± 2.04	27.08 ± 3.74	26.57 ± 3.65	**0.004**
MCV (fL)	27.05 ± 2.37	26.38 ± 2.81	26.50 ± 2.74	0.378
MCH (pg)	13.19 ± 0.81	12.38 ± 0.79	12.52 ± 0.85	**0.001**
MCHC (g/dL)	49.14 ± 4.82	47.21 ± 3.52	47.56 ± 3.83	0.068
RDW (fL)	23.58 ± 1.68	23.36 ± 2.07	23.40 ± 1.99	0.687
RDW (%)	35.66 ± 4.11	39.25 ± 1.91	38.60 ± 2.79	**0.003**
RET ($X10^3/\mu L$)	14.10 ± 3.48	11.71 ± 4.96	12.08 ± 4.83	**0.101**
RET (%)	0.16 ± 0.04	0.11 ± 0.05	0.12 ± 0.05	**0.002**
RET-HBG (pg)	21.32 ± 6.70	24.56 ± 6.51	24.06 ± 6.60	**0.104**
WBC ($X10^3/\mu L$)	12.84 ± 2.42	10.83 ± 2.65	11.19 ± 2.71	**0.017**
NEU ($X10^3/\mu L$)	7.31 ± 2.12	5.93 ± 1.77	6.18 ± 1.90	**0.033**
LYM ($X10^3/\mu L$)	4.22 ± 1.52	3.83 ± 1.32	3.90 ± 1.35	0.298
MONO ($X10^3/\mu L$)	0.55 ± 0.29	0.49 ± 0.17	0.50 ± 0.19	0.434
EOS ($X10^3/\mu L$)	0.73 ± 0.31	0.55 ± 0.34	0.58 ± 0.34	0.062
BASO ($X10^3/\mu L$)	0.02 ± 0.02	0.02 ± 0.02	0.02 ± 0.02	0.844
PLT ($X10^3/\mu L$)	238.54 ± 46.84	178.65 ± 44.33	187.81 ± 49.44	**0.001**
PCT (%)	0.18 ± 0.03	0.14 ± 0.03	0.14 ± 0.04	**0.001**
MPV (fL)	7.73 ± 0.41	7.71 ± 0.55	7.71 ± 0.53	0.902

Note: Red blood cell (RBC). Packed Cells Volume (PCV). Haemoglobin (HGB). Mean cell volume (MCV). Mean corpuscular haemoglobin (MCH). Mean corpuscular haemoglobin concentration (MCHC). Red blood cell distribution width (RDW). Reticulocytes (RETIC) Reticulocyte haemoglobin (RETIC-HGB). White blood cell (WBC). Neutrophils (NEU) Lymphocytes (LYM). Monocytes (MONO). Eosinophils (EOS). Basophils (BASO). Platelet (PLT). Plateletcrit (PCT) and Mean platelet volume (MPV). * Statistically significant is highlighted. P-Value for the Student T test has been included.

Table 6
Mean ± standard deviation of biochemical variables of adult Canarian camels (*Camelus dromedarius*) (N = 89). For comparison between sexes only animals older than 1 year have been included.

Parameters	Males (n = 16)	Females (n = 73)	Adults (n = 89)	P-value*
CREA (mg/dL)	1.61 ± 0.30	1.62 ± 0.27	1.62 ± 0.28	0.839
BUN (mg/dL)	7.69 ± 1.85	8.23 ± 3.88	8.13 ± 3.60	0.586
BUN/CREA	4.89 ± 1.76	5.27 ± 2.80	5.20 ± 2.64	0.587
Phosphorus (mg/dL)	6.97 ± 0.91	5.89 ± 0.84	6.05 ± 0.93	**0.001**
Calcium (mg/dL)	ND	8.56 ± 0.24	8.56 ± 0.24	–
Total proteins (g/dL)	6.09 ± 0.49	5.82 ± 0.57	5.87 ± 0.57	0.078
Albumin (g/dL)	3.38 ± 0.23	3.35 ± 0.50	3.35 ± 0.47	0.672
Globulin (g/dL)	2.79 ± 0.36	2.45 ± 0.22	2.50 ± 0.27	**0.005**
A/G ratio	1.23 ± 0.13	1.37 ± 0.24	1.35 ± 0.23	**0.039**
ALT (IU/L)	31.25 ± 11.82	30.58 ± 9.56	30.70 ± 9.94	0.807
ALKP (IU/L)	54.00 ± 8.19	64.00 ± 18.23	62.85 ± 17.56	0.364
GGT (IU/L)	11.67 ± 2.90	11.61 ± 6.63	11.62 ± 6.21	0.976
TBIL (mg/dl)	0.20 ± 0.08	0.28 ± 0.15	0.27 ± 0.14	0.184
CHOL (mg/dl)	35.27 ± 17.10	34.81 ± 22.27	34.89 ± 21.36	0.891
AMYL (IU/L)	601.58 ± 98.63	663.49 ± 260.28	654.32 ± 243.74	0.420
LIPA (IU/L)	32.67 ± 23.11	30.91 ± 17.48	31.12 ± 17.95	0.781

* Note: BUN = blood urea nitrogen. CREA = creatinine. A/G = albumin-globulin ratio. ALT = alanine aminotransferase. ALKP = alkaline phosphatase. GGT = gamma-glutamyl transpeptidase. TBIL = Total bilirubin. CHOL = cholesterol. AMYL = amylase. LIPA = lipase. SD = standard deviation. Min = minimum value. Max = maximum value. * Statistically significant is highlighted in bold. P-Value for the Student T test has been included.

camels in Kuwait (Mohamed and Hussein, 1999). A study conducted in camels in Bangladesh reported an higher haematocrit value and a reference (Islam et al., 2019) to those of our study, as well as those reported in male and female camels in Pakistan (Farooq et al., 2011).

Comparisons of our results to previous studies found that WBC counts and reference range were in agreement with reference range stated for "old world" camels in the literature (Elitok and Cirak, 2018; Farooq et al., 2011; Lamo et al., 2020; Mohamed and Hussein, 1999; Waziri et al., 2019). Similarly, Faye & Bengoumi (2018) reported a wide range of WBC values (9.7–20.1 $X10^3/\mu L$) in dromedary camels, which was higher than observed in ruminants (Faye and Bengoumi, 2018; Weiss and Wardrop, 2010). Moreover, the leukocyte formula of Canary dromedary camels was similar to previous studies (Faye and Bengoumi, 2018), with a predominance of polynuclear neutrophils ranging from 50.9 to 59.0% (Ghodsian et al., 1978; Weiss and Wardrop, 2010), which was a higher than observed in other domestic herbivores (Faye and Bengoumi, 2018). The same was observed for the other white blood cell types.

Our biochemical profile analysis revealed lower mean creatinine and blood urea nitrogen levels compared to those reported for camels in Kuwait (Elitok and Cirak, 2018; Farooq et al., 2011; Lamo et al., 2020; Mohamed and Hussein, 1999; Waziri et al., 2019) or for camels in Bangladesh (Islam et al., 2019). Lower creatinine levels were reported by Ragab H. Mohamed et al. (2021) in non-pregnant dromedary camels in Alexandria (Egypt). The mean creatinine level in camels in Sudan during the hot summer dry season was similar to this study, but higher compared to the rainy, hot summer rainy and wet winter dry season (Babeker et al., 2013). An increase in mean BUN level has been observed with higher protein rations and during the hot and dry season (Babeker et al., 2013). Thus, the results may be associated with the particular climatic

Table 7
Mean ± standard deviation of haematological variables of female adult Canarian camels (*Camelus dromedarius*) (N = 73). Comparison related to pregnancy status.

Parameters	Pregnant females (n = 20)	Non-pregnant females (n =53)	Total (n = 73)	P-value*
RBC ($X10^6$/μL)	10.15 ± 1.10	10.34 ± 1.19	10.29 ± 1.16	0.609
HBG (g/dL)	12.68 ± 1.32	12.74 ± 1.62	12.72 ± 1.54	0.684
PCV (%)	27.69 ± 3.21	26.85 ± 3.92	27.08 ± 3.74	0.571
MCV (fL)	27.35 ± 2.11	26.02 ± 2.97	26.38 ± 2.81	0.124
MCH (pg)	12.51 ± 0.64	12.33 ± 0.84	12.38 ± 0.79	0.841
MCHC (g/dL)	45.89 ± 2.21	47.42 ± 3.81	47.21 ± 3.52	**0.019**
RDW (fL)	24.33 ± 2.05	22.99 ± 1.97	23.36 ± 2.07	**0.031**
RDW (%)	39.33 ± 1.55	39.22 ± 2.04	39.25 ± 1.91	0.630
RET ($X10^3$/μL)	10.12 ± 4.13	12.33 ± 5.15	11.71 ± 4.96	0.063
RET (%)	0.10 ± 0.04	0.12 ± 0.05	0.11 ± 0.05	**0.026**
RET-HBG (pg)	26.20 ± 8.03	23.93 ± 5.78	24.56 ± 6.51	0.262
WBC ($X10^3$/μL)	9.12 ± 2.08	11.46 ± 2.63	10.83 ± 2.65	**0.021**
NEU ($X10^3$/μL)	5.67 ± 1.97	6.14 ± 1.66	5.93 ± 1.77	0.288
LYM ($X10^3$/μL)	2.97 ± 0.94	4.21 ± 1.30	3.83 ± 1.32	**0.011**
MONO ($X10^3$/μL)	0.46 ± 0.16	0.52 ± 0.16	0.49 ± 0.17	0.632
EOS ($X10^3$/μL)	0.54 ± 0.51	0.57 ± 0.26	0.55 ± 0.34	0.062
BASO ($X10^3$/μL)	0.02 ± 0.02	0.02 ± 0.02	0.02 ± 0.02	0.330
PLT ($X10^3$/μL)	153.16 ± 33.84	188.45 ± 41.30	178.65 ± 44.33	**0.012**
PCT (%)	0.12 ± 0.03	0.14 ± 0.03	0.14 ± 0.03	**0.015**
MPV (fL)	7.87 ± 0.81	7.66 ± 0.41	7.71 ± 0.55	0.156

Note: Red blood cell (RBC). Packed Cells Volume (PCV). Haemoglobin (HGB). Mean cell volume (MCV). Mean corpuscular haemoglobin (MCH). Mean corpuscular haemoglobin concentration (MCHC). Red blood cell distribution width (RDW). Reticulocytes (RETIC) Reticulocyte haemoglobin (RETIC-HGB). White blood cell (WBC). Neutrophils (NEU) Lymphocytes (LYM). Monocytes (MONO). Eosinophils (EOS). Basophils (BASO). Platelet (PLT). Plateletcrit (PCT) and Mean platelet volume (MPV). * Statistically significant is highlighted in bold. P-Value for the Student T test has been included.

Table 8
Mean ± standard deviation of biochemical variables of female adult Canarian camels (*Camelus dromedarius*) (N = 73). Comparison related to pregnancy status.

Parameters*	Pregnant females (n = 20)	Non-pregnant females (n = 53)	Total (n = 73)	P-value
CREA (mg/dL)	1.70 ± 0.18	1.59 ± 0.30	1.62 ± 0.27	**0.002**
BUN (mg/dL)	5.80 ± 1.67	9.15 ± 4.08	8.23 ± 3.88	**0.001**
BUN/CREA	3.55 ± 0.89	5.92 ± 3.00	5.27 ± 2.80	**0.001**
Phosphorus (mg/dL)	5.58 ± 0.76	6.02 ± 0.84	5.89 ± 0.84	0.084
Calcium (mg/dL)	ND	8.56 ± 0.24	8.56 ± 0.24	–
Total proteins (g/dL)	5.90 ± 0.47	5.79 ± 0.61	5.82 ± 0.57	0.171
Albumin (g/dL)	3.50 ± 0.33	3.29 ± 0.54	3.35 ± 0.50	**0.015**
Globulin (g/dL)	2.38 ± 0.24	2.48 ± 0.21	2.45 ± 0.22	0.099
A/G ratio	1.48 ± 0.17	1.33 ± 0.25	1.37 ± 0.24	**0.002**
ALT (IU/L)	29.80 ± 6.67	30.87 ± 10.49	30.58 ± 9.56	0.872
ALKP (IU/L)	ND	64.00 ± 18.23	64.00 ± 18.23	–
GGT (IU/L)	9.95 ± 2.95	12.29 ± 7.57	11.61 ± 6.63	0.148
TBIL (mg/dl)	0.24 ± 0.07	0.29 ± 0.17	0.28 ± 0.15	0.067
CHOL (mg/dl)	46.42 ± 22.93	28.51 ± 19.45	34.81 ± 22.27	**0.006**
AMYL (IU/L)	468.50 ± 81.69	743.08 ± 266.50	663.49 ± 260.28	**0.001**
LIPA (IU/L)	19.33 ± 9.48	32.65 ± 17.81	30.91 ± 17.48	0.097

* Note: BUN = blood urea nitrogen. CREA = creatinine. A/G = albumin-globulin ratio. ALT = alanine aminotransferase. ALKP = alkaline phosphatase. GGT = gamma-glutamyl transpeptidase. TBIL = Total bilirubin. CHOL = cholesterol. AMYL = amylase. LIPA = lipase. ND = Not determined. * Statistically significant is highlighted in bold. P-Value for the Student T test has been included.

conditions. Further research looking at the relationship between dietary protein level and BUN are needed.

A study conducted in camels in Sudan by Babeker et al., (2013) found similar results in mean calcium level and were observed to be higher in the hot dry summer than in the rainy hot summer and dry wet winter seasons. These results are comparable to those reported in camels in Kuwait (Elitok and Cirak, 2018; Farooq et al., 2011; Lamo et al., 2020; Mohamed and Hussein, 1999; Waziri et al., 2019) and similar to our own findings. Conversely, our mean phosphorus levels were higher than those reported in camels in Kuwait (Elitok and Cirak, 2018; Farooq et al., 2011; Lamo et al., 2020; Mohamed and Hussein, 1999; Waziri et al., 2019). Amin et al. (2007) documented variations in serum phosphorus concentration depending on the season, with statistical differences found between dry season and green season. Our results related to serum phosphorus are similar to those described during the green season in camels in Sudan in this study.

Variation in the concentration of total protein, albumin and globulin have been widely reported in the literature (Faye and Bengoumi, 2018). In Sudan, Amin et al. (2007) found no significant variation in the mean albumin concentration across seasons. However, a higher globulin concentration was seen during the dry season in comparison to the green season, resulting in the same variation in mean total protein. Similarly, Babeker et al. (2013) discovered the highest level of albumin throughout the dry and wet winter, but the lowest total protein or mean A/G ratio. Conversely, the higher total protein coincided with a mean albumin level and mean A/G ration during the hot rainy summer. The lowest albumin level and total protein value were observed, resulting in a lower mean A/G ration during the hot dry summer. In camels in Bangladesh, the lowest mean A/G ratio was reported by Islam et al. (2019). Another study conducted in camels in Libya revealed a total protein and albumin concentration with a corresponding higher mean A/G ratio. Total protein concentration of 6.26 ± 0.60 g/dl were reported in Kuwait (Elitok and Cirak, 2018; Farooq et al., 2011; Lamo et al., 2020; Mohamed and Hussein, 1999; Waziri et al., 2019). However, no information regarding the A/G ratio was provided. Consequently, our results are similar to those

published in dry seasons in other regions. Despite adaptation to dry and arid ecosystems, nutritional status is known to affect the overall performance of dromedaries. Such harsh conditions induce severe fluctuations in their nutritional status and lead to significant alterations in their haematological and biochemical parameters, such as glucose, urea, phosphorus and calcium levels, which have been reported to decrease during the dry season (Amin et al., 2007). To the authors knowledge, no studies have been conducted on variations in the other biochemical parameters related to geoclimatic conditions.

4.2. Breed

The RBC counts in this study were higher than those reported for others breeds, such as Arabian race camels (Abdalla et al., 1988), Algerian camel breeds (Aichouni et al., 2010), Indian dromedary camels (Narnaware et al., 2016), and camels from the Eastern region of Saudi Arabia (AL-Busadah, 2007).

The RBC counts in this study were similar to those reported for indigenous Saudi Arabian camels (range 10.66 ± 0.31 to 16.16 ± 2.35 $\times$ 10^6/μL) (Hussein et al., 2012). Additionally, AL-Busadah (2007) found no effect of breed on WBC counts in three breeds of Arabian camels (Majaheem, Maghateer and Awarik).

Our results had similar values for BUN, creatinine, calcium, phosphorus, and total proteins to those reported for Arabian racing camel. However, values for ALT, GGT and TBIL were higher than the reference range (Abdalla et al., 1988; Mohamed and Hussein, 1999). Cholesterol values, although within the reference range, were lower than those in Saudi Arabian camels (AL-Busadah, 2007). Conversely, ALT, creatinine and BUN values were lower than expected, but within the reference range to those found in Arabia Saudi camels.

Our study demonstrated substantial variability in haematological and biochemical parameters among breeds investigated, as those reported by Faye & Bengoumi (2018). It is premature to attribute this variability to genetic factors and further studies should be conducted to dilucidated any breed-related differences across geographic regions are warranted to establish breed-specific reference ranges, a task that can benefit from recent genetic characterization of dromedaries.

4.3. Age

RBC results in young animals in this study were significantly higher than those of adults which is in contrast with previous studies (Ghodsian et al., 1978; Saeed and Hussein, 2008). In a study of the effects of epidural an intramuscular injection of xylazine in camels in Iran (Azari et al., 2012), RBC were substantially lower than ours results. This might be due to the age of the studied animals, which were 16 healthy young dromedaries weighing less than in our study. This variation is considered physiological and has no biological effect on the camels (Faye and Bengoumi, 2018).

WBC counts in the group of young camels was found to be statistically significantly higher than in adults ($P = 0.001$) and are similar to results described by Ghodsian et al. (1978). Our results are in line with those of a more recent research on the distribution of white blood cells subpopulations in newborn and adult dromedaries (Gaashan et al., 2020). However, Ghodsian et al. (1978) found slightly higher numbers of lymphocytes in adult and old animals compared to young camels, whereas in our study, statistical differences in lymphocyte counts between young animals and old animals were observed in the opposite direction. Several authors are not in agreement with this statement (Chartier et al., 1986; Farooq et al., 2011). Therefore, the conclusion of Ghodsian et al. (1978) should be revised. Other studies have not shown age-related differences in haematological parameters (Chartier et al., 1986). Similarly, no age-related differences in eosinophils ($P = 0.443$) or basophils ($P = 0.097$) were found in our study. Variations in WBC counts at birth and during the first month of age have also been reported (Tharwat et al., 2015). Higher levels of several parameters such as WBC, lymphocyte, and neutrophil counts at birth or during weeks 1, 2, 3 and 4 of age have been attributed to higher cortisol concentration occurring late in pregnancy and during parturition. Thus, further research is necessary to gain a deeper comprehension of how age influences haematological variables in dromedaries.

In other studies in dromedary camels BUN or creatinine concentrations were not affected by age (Faye and Bengoumi, 2018). However, a statistical significantly higher creatinine level ($P = 0.001$) was found in the adult group than in the juvenile group. Evidence indicated that elevated BUN and creatinine levels are observed in camels with clinical sings of renal failure (Mehra et al., 2019). Since the animals in the current research were healthy, these variations may be attributed to physiological conditions, such as higher protein intake in the case of lactating camel calves or higher BUN levels during gestation in adult camels (Omidi et al., 2016). Inconsistent results regarding the influence of age on blood urea nitrogen and creatinine levels have been documented in dromedary camel (Faye and Bengoumi, 2018).

Phosphorus and calcium levels have been reported to be higher in young camels compared to adults (Rezakhani et al., 1997; Tharwat et al., 2015). These differences could be related to the mineral leakage through milk and/or the transfer to the foetus in pregnant camels. Consequently, further research should be conducted to determine the dietary requirement for calcium and phosphorus in the Canary Island Dromedary Camel.

Our research indicates a higher globulin level in males compared to female camels, and correspondingly, the A/G ratio. These results are in contrast to most of studies reporting no effect of sex on total protein and its fractions (Faye and Bengoumi, 2018). However, Ahmadi-hamedani et al. (2014) reported higher concentrations of gamma-globulins in female animals than in males, which could be attributed to physiological changes in females caused by lactation (Elkhair and Hartmann, 2012). Our results support this previous finding as lower albumin values were found in non-pregnant female compared to pregnant females. Nevertheless, the differences in globulin levels between pregnant and non-pregnant were not sufficient to explain the effects of gestation on globulin metabolism. Further research is needed to fully understand these differences.

The plasma cholesterol concentration in young camels was higher than in adults but all ranges values were within previous studies (Faye and Bengoumi, 2018). However, the results from this study appear to contradict those described by Nazifi et al. (2000) and Mohamed (2008), which demonstrated that the cholesterol concentration in adult camel plasma was greater than that of yearling and neonatal camels. Also, results show statistical difference in plasma cholesterol levels between pregnant camels and non-pregnant camels. It is suggested that the different observed between calves and adults in plasma cholesterol levels could be attributed to metabolic or physiological conditions (Al-Busadah, 2010; Faye and Bengoumi, 2018; Nazifi et al., 2000; Omer et al., 2008). Further research is necessary to elucidate the mechanisms underlying these differences.

Our results on ALKP are in agreement with a previous study, yet higher than the previously reported ranges in study including young animals (Faye and Bengoumi, 2018). The values obtained are similar to those reported in other ruminant species (Antonov and Malchevski, 1983; Djuricic et al., 2011; Onomi et al., 2019). The increased osteogenic activity in osteoblasts of young animals can be attributed to the catalytic activity of alanine aminotransferase (ALKP), suggesting its involvement in the growth process.

4.4. Sex

Significant sex-related differences in haematological and biochemical parameters have been described in the literature for camelids (Farooq et al., 2011; Narnaware et al., 2018; Abdalmula et al., 2019). In our study, lower haemoglobin, haematocrit and red blood cells results were observed in male camels compared to those in females. Our results are in contrast to those of Murphy (2014), who reported higher haemoglobin values in adult males of almost all mammalians species, including humans. Similarly, Abdalmula et al. (2019) found higher haematocrit and haemoglobin concentrations in female camels, but lower RBC counts compared to males. These differences could be attributed to the sexual activity (Faye and Bengoumi, 2018); however, in our study the majority of the male dromedary camels were castrated.

PCV values of males were lower than in female camels. Though other studies have reported a non-significant influence of sex (AL-Busadah, 2007) lower PCV in males were observed in all studied groups. This discrepancy may be attributed to the low sample size (10 per group) of the former study, thus failing to demonstrate any significant differences.

The RBC count for males was lower than the values observed described by Adah et al. (2017) in their experimental study. It was not possible to determine the influence of testosterone on the blood components of male individuals, as testosterone levels did not differ between fertile and infertile male camels with testicular defects (AL-Busadah, 2007). Androgen has been suggested to influence erythropoiesis through its impact on erythropoietin production (Delev et al., 2016). Further research is necessary to elucidate the effect of gender on haematological measures in the dromedary camel.

In comparison to Abdalmula et al. (2019), this study found higher total WBC counts between males and females; no sex differences were reported by Abdalmula et al. (2019). Additionally, statistically higher neutrophils values were found for males compared to female camels in this study. This is in contrast to the study of Abdalmula et al. (2019) were higher values were found in females compared to males camels. The number of male animals in both experiments is comparable, yet the reproductive status of the two groups is indeterminate, thus impeding a comparison. Further research is necessary to gain insight into the basis of such divergences. We also observed a decrease in monocytes and lymphocytes values to those reported by Abdalmula et al. (2019). On the other hand, our results are comparable to those reported for non-rutting season (Al-Harbi, 2012; Faraz et al., 2020) in which an increase in white blood cell, neutrophil, lymphocyte counts, total cholesterol, glucose and LDL-L values were reported in the rutting season (Al-Harbi, 2012; Faraz et al., 2020).

5. Conclusions

The haematological and biochemical reference values measured in Canary Dromedary Camels (*Camelus dromedarius*) were found to be similar to those previously reported in dromedaries. Young animals had higher concentrations of RBC and WBC than adult animals. Additionally, higher values of Blood Albumin/Globulin (A/G) ratio, Urea Nitrogen (BUN), phosphorus, calcium, alkaline phosphatase, cholesterol, and lipase were observed in young animals compared to adults. Additionally, the female camels exhibited higher values of RBC, HGB and PCV when compared to the male camels. Furthermore, WBC count was observed to be higher in non-pregnant females compared to pregnant females. Differences in haematological and biochemical variables attributable to breeds could not be confirmed in this study and more studies are needed. This research could be a starting point for future investigation into breed differences in dromedaries.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We would like to thank Oasis Wildlife Park Fuerteventura for their collaboration and support for this study. Without their unconditional support this study would not have been possible.

Funding

This work was funded in part by Fundación Canaria de Investigación y Salud, under grant FIISIIC 22/32.

The funding agencies had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Adrián Melián has a grant from the predoctoral program for the training of research personnel of the Autonomous Community of the Canary Islands (TESIS2022010062).

Publication fees have been charged by the project ULPGC Excellence, funded by the Consejería de Economía, Conocimiento y Empleo del Gobierno de Canarias.

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