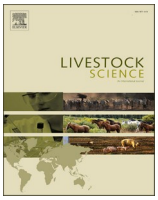
Livestock Science 292 (2025) 105646

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci



She-camel (*Camelus Dromedarius*) reproductive status and biochemical blood parameters assay in extensive breeding in southern Algeria

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HIGHLIGHTS

- Monitoring camel breeding is crucial to its success.
- Knowing the reproductive parameters of camels can improve production.
- Biochemical parameters in camels are essential elements for controlling breeding.

ARTICLE INFO

Keywords:
Blood biochemical parameters
Dromedary
Extensive environment
Reproduction parameters
Southern Algeria

ABSTRACT

Despite its importance to social and economic life in arid and semi-arid regions of Algeria, the dromedary camels has received little scientific attention in our country. This research focuses on two aspects of this animal in its natural environment. An individual monitoring of 14 reproductive parameters in 110 breeding camelids over 18 months and a single analysis of blood biochemical parameters in 212 animals was performed. The results reveal that the camel breeding season lasts from October to June, with an oestrus or "heat" duration (7.7 ± 1.4 days), mating duration (25±10 min), gestation duration (377 ± 9.4 days), labour duration (37.7 ± 15 min), delivery duration (37.9 ± 10 min), duration of return to oestrus after parturition (30.3 ± 11.7 days), average duration between parturition and fertilising oestrus (216 ± 137.7 days), rate of females returning to oestrus after parturition (77.2 %), fertility rate (54.11±10.6 %). Our findings for blood biochemical parameters show average glycemia (1.21 ± 0.04 g/l), proteinemia (63.8 ± 73 g/l), uremia (432.54 ± 17.4 mg/l), triglyceride levels (487.66 ± 86 mg/l), cholesterol (318.7 ± 32 mg/l), lipids (3 ± 0.31 g/l), calcium (87.45 ± 3.7 mg/l), phosphorus (46.5 ± 3.95 mg/l) and magnesium (23.47 ± 2.25 mg/l). Statistical analysis indicates that age, gender, and production status significantly affected most of blood biochemical parameters ($p \leq 0.001$). The findings were compared to those of other authors from other countries. Research, understanding, and improvement of the dromedary camels breeding system remain crucial in Algeria.

1. Introduction

The scientific and political communities must consider climate variability, drought, desertification, and decreasing rainfall, particularly in African countries where this phenomenon is exponential. In Algeria, two-thirds of the country's surface area (2383,000 km^2) is arid or semi-arid, and camel farming is a highly valuable economic and social activity and a source of income for the locals (Faraz et al., 2020; Traoré et al., 2019). It meets their requirements for meat, milk, hair, and work. The camel is the best-adapted species for living and reproducing in a water- and food-scarce environment (Chehma et al., 2023). According to the FAO, Algeria has a camel population estimated at 417 322 heads in

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https://doi.org/10.1016/j.livsci.2025.105646
Received 30 July 2024; Received in revised form 16 November 2024; Accepted 7 January 2025
Available online 9 January 2025

2020, representing 1.12 % of the world population, 1.29 % of the African population, and 7.48 % of the Maghreb population, with a mean annual growth corresponding to 3 % recorded between 1961 and 2018, and a milk volume of 15 080 tons produced in 2020 (Boudalia et al., 2023; Senoussi et al., 2023). However, livestock farming is essentially extensive and has low yields. Given this situation, significant efforts will be required over the next decade. Significant, in-depth studies of this animal in its natural environment and under actual farming conditions must be the focus of scientific research.

The hematological and biochemical status of livestock often provides valuable information for monitoring health status as well as controlling production and reproductive functions (Faye and Bengoumi, 2018; Rezakhani et al., 1997). Several studies in different regions have described variations in biochemical and reproductive parameters in camels depending on function of climatic, physiological and pathological conditions (Awad et al., 2018; Eltahir et al., 2016; Ghodsian et al., 1978; Manjunatha et al., 2022; Martín-Barrasa et al., 2023; Mohamed and Hussein, 1999; Nagy and Juhasz, 2012). In addition, these results may be distorted by various factors related to the age, breed, sex and reproductive status of the animal (Osman et Al-Busadah, 2000; Saeed et Hussein, 2008; Al-Harbi, 2012; Ebissy et al., 2019; Faraz et al., 2021; Faraz et al., 2020; Ibrahim et al., 2017; Jalali et al., 2018; Abdalla et al., 1988; Abdussamad et al., 2015; Aichouni et al., 2010) or its environment, such as the rearing system, diet, animal activity and geoclimatic conditions (Abdoslam et al., 2018; Amin et al., 2007; Elhag Eltahir, 2016; Farooq et al., 2011; Faye et Bengoumi, 2018; Islam et al., 2019; Lamo et al., 2020; Elitok et Cirak, 2018; Faraz et al., 2021; Adah et al., 2017; Auer et al., 2015). The data available on these biomarkers cannot therefore be extrapolated to the general population, as certain parameters must always be taken into account and regional and specific studies should be carried out.

There is little published data on camels under natural conditions (Eldirdiri et al., 1987; Faraz et al., 2018; Faraz, 2020). Current haematological, biochemical, and reproductive parameters are only fragmentarily available for the extensive husbandry practised in Algeria, making it difficult to monitor the camel industry.

The aim of this study is to determine the biochemical and reproductive parameters of camels in the Algerian context. Our work focuses on the variation of biochemical and reproductive parameters in relation to zootechnical parameters. Specifically, we investigated these parameters. Factors such as the breeding season, the duration of oestrus, the onset of first oestrus after calving, the time between calving and fertilisation oestrus, the abortion rate and the mortality rate of young and adult animals. We also determined biochemical parameters in the serum that provide information on the energy balance glycaemia (Gly), triglycerides (TG) and cholesterol (Chol)), the nitrogen balance urea and total protein (TP) and the mineral balance (calcium, phosphorus and magnesium) of the animals. These provide precise information on the nutritional and health status of the animals, detect nutritional deficiencies and diagnose subclinical pathological disorders.

2. Materials and methods

2.1. Ethics approval

All procedures were performed in accordance with the ethical standard of the Laboratory of Animal Reproduction Biotechnologies (LBRA), Institute of Veterinary Sciences, University of Blida1.

2.2. Study period and region

The study was conducted in the Oued Souf region from October 2019 to April 2021. The Oued Souf region is located in Algeria's northeastern Sahara. It has a total area of 14,500 km^2. The region's topography is flat and monotonous, with altitudes ranging from 20 to 120 m above sea level. It is mostly made up of dunes and is located in the Grand Erg Oriental basin (33° 22′ N; 6° 53′ E) (Fig. 1). The climate in Oued Souf is Saharan, with low rainfall, high temperatures, intense evaporation, and excessive solar radiation (*fr.climate-data.org*).

3. Methods

The survey used in this work has two components: individual monitoring of 110 camels' reproductive parameters for 18 months and one-time blood sampling to determine biochemical blood parameters for 212 heads.

3.1. Animal monitoring, data collection and blood sampling

A questionnaire in the form of individual monitoring sheets was used to collect data on 14 parameters, including: Breeding season, duration of oestrus, duration of mating, duration of gestation, duration of parturition, duration of calving, average duration of return to oestrus after parturition, average duration between parturition and fertilising oestrus, rate of return to oestrus in females after parturition (in the same season), fertility rate in the same season, abortion rate, incidence of dystocia, mortality rate of camels aged 0–12 months and mortality rate of adult animals.

A total of 110 Sahrawi camels aged between 7 and 12 years were selected at random, based on a draw at each farm. The selected animals were marked with a ribbon around their necks and the females were monitored from January 2021 to June 2022. Shepherds who participated in the survey were instructed to record all observations on each camel. Regular herd visits were made (once a month) to count the remaining females and record as much precise information (by date) as possible for each female between two successive visits.

During the humid season from November to January, blood samples were collected from 212 heads to measure biochemical blood parameters (glucose, total protein, urea, triglycerides, cholesterol, total lipids (TL), calcium, phosphorus, and magnesium). Variations are recorded based on age class (young individuals aged two to four months and one to two years and adults aged over 5 years) and the production status of the female. Blood samples are drawn from the jugular vein in the morning, collected in EDTA-tubes, and stored in a cool place before being centrifuged at 3000 rpm for 10 min. The plasma was aliquoted and stored in the laboratory at -25 °C for later analysis.

3.2. Laboratory analysis

3.2.1. Biochemical parameters analysis

According to the supplier's instructions, the "Bio Maghreb" kits, Tunisia, were used to determine biochemical parameters. The colorimetric method was used to determine minerals (calcium, phosphorus and magnesium) (Kit ref. 20054, 20082 and 20071). The colorimetric enzymatic method was used to determine the triglycerides (Kit ref. 20032) and cholesterol (ref: 20112). The glucose level was done with the GOD PAP enzymatic method (Kit ref. 20127). The Biuret colorimetric method was used to determine the total protein (Kit ref. 20161), and finally the urea level was done by Berthelot method (Kit ref. 20141).

3.2.2. Expression of results and statistical analysis

To compare the mean values of the blood biochemical parameters investigated in this study, the animals were divided into three age groups, sexes, and reproductive statuses for adult females: two to four months, one to two years, and over five years.To determine the influence of reproductive status on blood biochemical parameters, females over 5 years were divided into two groups. Pregnant and lactating camels were compared to non-producing females to determine the effect of reproductive status on these parameters. During the wet season, the effect of age, gender, and reproductive status was investigated. The parameters for each group are expressed as the mean affected by the mean (SEM) standard error. A general linear model (Proc GLM) with SAS software

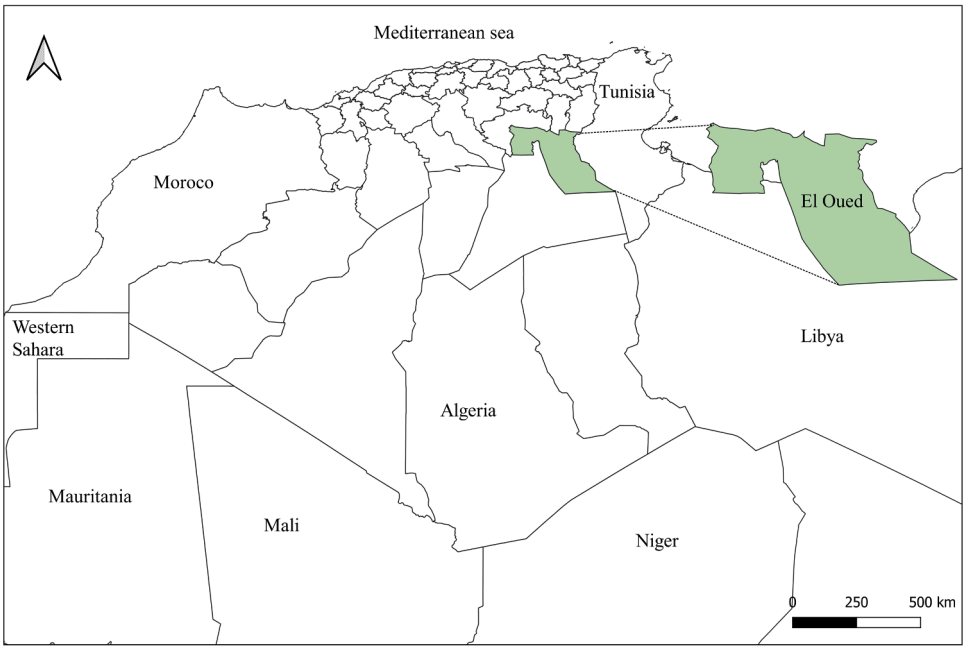

Fig. 1. Representation of the study area.

(SAS, 2001) was used to compare means between different groups (sex, age, and reproductive status). Differences were considered significant at the probability threshold ($p < 0.05$).

4. Results

4.1. Characteristics of study population

Of the 212 camels, 135 females and 77 males (Table 1) with a sex ratio of 1.75 (F/M). All the animals underwent biochemical analysis. In addition, the 110 camels selected in this study for reproductive parameters were from 10 extensive farms. The animals selected for this study belonged to three age groups: 2–4 months ($n = 60$), 12–24 months ($n = 44$) and over 24 months ($n = 108$) (Table 1).

4.2. Monitoring of reproduction parameters

In this study, the heat duration of the female camels varied between 2 and 10 days, with an average duration of 7.7 ± 1.4 days. The average mating time was 25 ± 10 min for the 46 females observed. The gestation period in dromedaries was 377 ± 9.4 days. The calving period was 37.7 ± 15 min, with two extremes of 25 and 65 min. The average duration of return to heat after calving was 30.3 ± 11.7 days. However, the average time between parturition and fertilizing heat was 165 and 346 days (Table 2).

In terms of reproductive indices, this study showed a rate of 77.2 ± 7.8 % of females returning to heat after parturition. The survey reported a female fertility rate of 54.1 ± 10.6 % (46/85), an abortion rate of approximately 15 %, and an estimated incidence of dystocia of 2.5 %. Finally, we reported a mortality rate before the age of one year of 20.5 ± 12.6 % and an adult mortality rate of 7.2 ± 4.8 % (8/110) (Table 3).

Table 1
Characteristics of camels included in the biochemical parameters survey.

Gender Age	Male	Female	Total
2–4 months	30	30	60
12–24 months	20	24	44
>2 months	27	81	108
Total	77	135	212

Table 2
Monitoring results for camel breeding parameters.

Parameters	Total	Average	Min and Max
Heat duration	N = 46	7.7 ± 1.4 days	2–10 days
Duration of mating	N = 46	25±10 min	10–35 min
Gestation period (days)	N = 46	377±9.4 days	368–387 days
Calving period	N = 46	37.7 ± 15 min	25–65 min
Duration of issue	N = 31	37.9 ± 10.5 min	25–50 min
Average duration of return to heat after calving	N = 62	30.3 ± 11.7 days	18–45 days
Average time between parturition and fertilizing heat	N = 46	216±137.7 days	165–346 days

4.3. Blood biochemical parameters

The results of biochemical analyses of 210 camels are detailed in Tables 4, 5, 6, and 7. The mean levels of glucose, total protein, urea, triglycerides, cholesterol, calcium, and magnesium were 1.21±0.04 g/l, 63.87±3 g/l, 432.54±17.44 mg/l, 487.66±36 mg/l, 318.7 ± 32 mg/l, 3 ± 0.31 g/l, 87.45±2.7 mg/l, 46.5 ± 3.95 mg/l, and 23.47±2.25 mg/l, respectively.

Table 4 shows statistical differences between young and adult

Table 3
Camel breeding performance.

Parameters	Number	Frequency (%)
Females returning to heat after parturition	110	77.2 ± 7.8 % (85/110)
Fertility rate	85	54.11±10.6 % (46/85)
Abortion rate	46	15.2 ± 10.3 % (7/46)
Frequency of dystocia	39	2.5 ± 4.9 % (1/39)
Mortality rate 0–12 months	39	20.5 ± 12.6 % (8/39)
Adult mortality rate	110	7.2 ± 4.8 % (8/110)

Table 4
Biochemical parameters according to age.

Parameter	2 to 4 months	12 to 24 months	> 24 months	Average value
Blood glucose (g/l)	1.6 ± 0.06***	1.16 ±0.05***	0.73 ±0.02**	1.21±0.04
Total protein (g/l)	64.2 ± 6.4 NS	62±1.8NS	65.25 ±0.9NS	63.87±3
Urea (mg/l)	492 ±24.39NS	425 ±17.59NS	375 ±11.53NS	432.54 ±17.44
Triglycerides (mg/l)	678.41 ±58**	478.33 ±34**	297.25 ±17**	487.66±36
Cholesterol (mg/l)	470±38**	204±33**	247±26NS	318.7 ± 32
Total lipids (g/l)	2.63±0.26 NS	2.85±0.32 NS	3.81±0.36 NS	3 ± 0.31
Calcemia (mg/l)	92.06 ±3.8**	86.98±3.41 NS	88.16 ±1.29 NS	87.45±2.7
Phosphoremia (mg/l)	94.49 ±7.67***	22.27±2.64 NS	22.97 ±1.55 NS	46.5 ± 3.95
Magnesemia (mg/l)	22.30±4.61 NS	24.93±1.48 NS	21.72 ±0.68 NS	23.47±2.25

NS *Non-significant (p>0.05).*
** *(p < 0.01),.*
*** *(p < 0.001).*

Table 5
Biochemical parameters according to sex.

Parameter	Male	female	Meaning
Blood glucose (g/l)	1.31±0.049	1.15±0.046	p < 0.01**
Total protein (g/l)	63.01±2.2	73.60±3.86	p < 0.01**
Urea (mg/l)	440.17±22.22	424.84±10.33	p>0.05 NS
Triglycerides (mg/l)	505.99±24.56	469.50±48.13	p>0.05 NS
Cholesterol (mg/l)	322.87±31.32	325.77±14.86	p>0.05 NS
Total lipids (g/l)	2.89±0.30	3.31±0.32	p>0.05 NS
Calcemia (mg/l)	86.66±3.25	88.27±2.34	p>0.05 NS
Phosphoremia (mg/l)	56.41±4.49	36.7 ± 3.26	p < 0.01**
Magnesemia (mg/l)	25.23±1.88	20.73±2.58	p>0.05 NS

NS : Non-significant (p>0.05).
** (p < 0.01), ***(p < 0.001).

Table 6
Biochemical parameters according to physiological stage.

Parameter	Gestation	Lactation	Non-gestation	Meaning
Blood glucose (g/l)	1.18±0.71	1.08±0.081	0.73±0.02	p < 0.01**
Total protein (g/l)	96.4 ± 1.73	66.17±1.82	69.05±0.74	p>0.05NS
Urea (mg/l)	441.6 ± 40.88	421.57 ±25.11	369.45 ±7.99	p < 0.01**
Triglycerides (mg/l)	377.35 ±24.34	307.03 ±34.86	297±12.66	p>0.05 NS
Cholesterol (mg/l)	304±26.08	268±29.86	242.42 ±9.26	p>0.05 NS
Total lipids (g/l)	3.98±0.09	4.25±0.76	4.03±0.39	p>0.05 NS
Calcemia (mg/l)	61.34±8.20	68.78 ±29.86	92.10±1.29	p < 0.01**
Phosphoremia (mg/l)	81.85 ±10.52	47.66±9.5	18.69±0.75	p < 0.001***
Magnesemia (mg/l)	31.61±2.57	21.12±2.35	20.44±0.54	p>0.05 NS

NS : Non-significant (p>0.05).
** (p < 0.01).
*** (p < 0.001).

animals in the biochemical parameters studied, with the exception of urea, total protein, total lipid, and magnesium. The glucose and triglyceride levels were significantly higher in the three age groups ($P <$ 0.01–0.001). Indeed, the levels of glucose and triglyceride were significantly higher in young camels aged 2 to 4 months and 12 to 24 months than in camels older than 24 months ($p <$ 0.01–0.001). In contrast, the cholesterol levels were significantly higher in animals aged 2 to 4 months and 12 to 24 months than in camels older than 24 months. Calcaemia and phosphoraemia were significantly higher in camels aged 2 to 4 months than in the other age groups (Table 4)

The comparison of biochemical parameters between males and females is shown in Table 5. The male blood values for glucose, phosphorus and magnesia were significantly higher compared to the females ($P <$ 0.01). However, total protein in the blood was higher in females than in males (Table 5, $p <$ 0.01).

The results of the biochemical parameters in the three groups of the physiological state are shown in Table 6. The values of blood glucose, urea and phosphoraemia were statistically higher in pregnant female than in lactating and non-pregnant female. Calcaemia was higher in the non-pregnant female than in the pregnant and lactating bitches (Table 6).

The results of correlation and logistic regression analyses of the various biochemical parameters are reported in Tables 7, 8, and Fig. 2. There was no statistically significant correlation for cholesterol, urea and phosphotemia ($p >$ 0.05, Table 7). Analysis of variance showed that the values for glycaemia, total protein, triglycerides, total lipid, calcium and magnesium were statistically different in the different camel groups ($p <$ 0.05), taking into account age, sex and reproductive status (Table 7). In addition, correlation analysis showed that the glycaemic score was positively correlated with cholesterol ($R^2 =$ 0.60), triglycerides ($R^2 =$ 0.73), total lipid ($R^2 =$ 0.68) and phosphorus ($R^2 =$ 0.78; Fig. 2). There was also a positive correlation between cholesterol, total lipids ($R^2 =$ 0.61) and phosphorus ($R^2 =$ 0.69; Fig. 2) and between triglycerides, total lipids (R^2=0.74) and phosphorus ($R^2 =$ 0.60; Fig. 2). Finally, there was a positive correlation between total lipids and phosphorus ($R^2 =$ 0.62; Fig. 2). The other parameters were not correlated with each other (R^2<0.50; Table 7 **and** Fig. 2).

Table 8 shows the results of the logistic regression model for the different camel groups. The values of the blood biochemical parameters, showing blood glucose (OR: 0.24, CI: 0.12–0.49), total protein (OR= 1.04, CI: 1.03–1.05), triglycerides (OR= 0.96, CI: 0.994–0.997), total lipids (OR= 1.98, CI: 1.06–2.44), calcium (OR= 1, CI: 0.99–1) and magnesium (OR= 0.95, CI: 0.92–0.97), all significantly associated with the different dromedary groups in this study.

5. Discussion

Skidmore et al. (2013) described the camel as a species with seasonal sexual activity. It is only noted during the humid season, when the availability of food from ephemeral plants increases after the first autumn rains (Marai et al., 2009). The camel is a species that has induced ovulation (Cooper et al., 1992; El-Wishy, 1989; Skidmore, 2011; Skidmore et al., 2013; Zarrouk et al., 2003). Wilson (1989) hypothesized that seasonality is less pronounced in females than in males. This is demonstrated by the year-round dispersal of births (Musa et al., 1993; Wilson, 1989). Marie and Anouassi (1987) demonstrated that camel sexual activity could be continuous, whereas it is seasonal in males. The sexual season varies according to geographical location, climatic conditions, and nutritional status. In Algeria, camel reproduction takes place between October and March north of the Sahara and between January and June in the far south. The breeding males are only present with the female during this season (Kelanemer et al., 2015).

Puberty occurs between 30 and 36 months for both males and females. Some younger camels have already mated (El-Harairy et al., 2019). Puberty is usually determined by food availability and breed. Breeders select females based on their size at first parturition and their milk production. Heat is a physiological state in which the female is ready to mate and is accompanied by behavioral and physiological signs that vary in intensity depending on the individual (Sghiri, 1987). A female in heat is easy to recognize. She becomes nervous and anxious, often approaching the male and barracking near him (Anouassi, 1994;

Table 7
Biochemical parameters according to age, sex and physiological stage.

Parameters	Groups								SEM	p-value Groups effect	R^2
	Class A1	Class A2	Class B1	Class B2	Class C1	Class C2	Class D1	Class D2			
Gly	1.68[a]	1.48 [b]	1.11 [cd]	1.19 [c]	1.06 [d]	0.75 [e]	1.18 [c]	1.09 [cd]	0.025	***	0.82
PT	68.31 [cb]	63.61 [ced]	61.71 [e]	62.12 [ed]	60.12 [e]	70.09 [b]	97.79 [a]	66.77 [cbd]	1.07	***	0.77
Uree	484.46 [ab]	519.27 [a]	482.81 [ab]	368.65 [bc]	331.64 [c]	372.71 [bc]	454.73 [abc]	424.15 [abc]	35.21	NS	0.13
Chol	416.11 [a]	370.05 [b]	310.95 [ac]	279.55 [cd]	214.20 [e]	258.95 [d]	311.39 [c]	269.29 [cd]	10.15	NS	0.58
TG	619.77 [a]	614.20 [a]	525.80 [b]	501.24[b]	305.82[d]	301.45 [d]	385.48 [c]	306.45 [d]	12.94	***	0.77
LT	1.96 [e]	2.34 [d]	2.92 [c]	2.93 [c]	3.78 [b]	4.03 [ab]	3.06 [c]	4.30 [a]	0.084	***	0.75
Ca	97.76 [a]	91.05 [b]	89.98 [b]	88.70 [bc]	84.46 [cd]	92.61 [b]	71.67 [e]	80.11 [d]	0.99	***	0.65
P	112.24 [a]	90.23 [b]	26.66 [e]	18.78 [f]	27.13 [e]	18.66 [f]	41.61 [d]	49.12 [c]	1.26	NS	0.96
Mg	28.15 [bc]	30.10 [ab]	26.55 [cd]	23.11 [ef]	24.34 [ed]	20.33 [f]	31.99 [a]	20.98 [f]	0.74	***	0.51

By row, the same letter (a, b, c, d, e, f) is attributed to values not presenting any statistical difference between them (p-value>0.05).
*** : $p < 0.0001$. R^2 is the coefficient of determination, and SEM is the standard error of the mean. Class A1= very young males,A2= very young females, Class B1= = young males, B2= = young females, C1 = adult males,C2= = adult females, D1 = producing females, D2= = non-producing females.

Table 8
Multiple regression of different biochemical parameters in different camel classes.

Variable	OR [CI]	p-value	R^2
GLY	0.247 [0.12–0.49]	0.0000***	0.82
PT	1.04 [1.03–1.05]	0.0000***	0.77
Cholesterol	0.99 [0.99–1.00]	0.7773[NS]	0.13
Urea	0.99 [0.99–1.00]	0.8917[NS]	0.58
TG	0.96 [0.994–0.997]	0.0000***	0.77
LT	1.98 [1.06–2.44]	0.0000***	0.75
Ca	0.92 [0.90–0.93]	0.0000***	0.65
p	1 [0.99–1.00]	0.7818[NS]	0.96
Mg	0.95 [0.92–0.97]	0.0005***	0.51

[NS] : Non-significant.
*** ($p < 0.001$)
Gly: Glycose, PT: Total Protein, UREE: Urea, CHOL: Cholesterol, TG: Triglycerides, LT: Total Lipide, Ca: Calcium, P: Phosphore, Mg: Magenisium.

Wilson, 1989). She makes a rhythmic noise that is typical of her condition. Her tail is taut and stiff, pointing backward and vertically wagging. When the male sniffs her vulva, she emits small streams of urine (Anouassi, 1994).

Our results show that heat can last between two and ten days, on average 7.7 ± 1.4 days. In comparison, Williamson and Payne (1978) and Mukasa-Mugerwa (1985) reported 6 to 8 days and 3 to 4 days, respectively. After mating, the male forces the female into a sternal decubitus position. The male seeks the vulva, and the penis enters through rotation on its longitudinal axis (Wilson, 1989). Mating can last on average 10 and 25 min (25 ± 10 min) in two to three sessions recorded in this survey, which is consistent with the findings of Joshi et al. (1980) and Sghiri (1987) reporting similar durations. If mating is successful, gestation lasts on average 377 ± 9.4 days (368 to 387 days). Similar results were reported by Sghiri and Driancourt (1999) (375 ± 12.6 days) and Wilson (1989) (377 days). In contrast, Khanna et al. (1990) reported a longer duration (390 days).

During labour, the camel either is in the sternal or lateral decubitus position or alternates between the two. However, the lateral position is still the most common. The expulsion of the foetus takes an average of 37.7 ± 15 min (25 to 65 min). A duration of 25 to 40 min is given in the literature. Camel delivery takes an average of 37.9 ± 10.5 min (25 to 50 min). The authors report a duration of 25 to 40 min. The duration of uterine involution in camels was reported by Kelanemer et al. (2023) and El-Harairy et al. (2019) to be 18 to 21 days. The return to heat is rapid, with a duration of 30.3 ± 11.7 days (Table 2). El-Harairy et al. (2019) reported 18 to 45 days, while Sghiri (1987) noted 14 to 40 days. On the other hand, the average time between calving and fertilizing heat is 216.6 ± 137.7 days. According to Elias (1990), fertile mating only occurs when calving takes place early in the breeding season.

During the same breeding season, more than 77.2 % of camels came back into heat, with a fertility rate of 54 %. The annual fertility was over 65 % (rainy year, abundant food). According to Sghiri (1987), young females (8 to 11 years old) have a higher rate of resumption of follicular activity and fertility (88.9 %) than older females (50 %). Despite this relatively acceptable fertility, the abortion rate and mortality rate of young and adult camels remain the most limiting factors for camel population development, with rates of 15 %, 22 %, and 7.3 %, respectively. Wilson (1984) estimates that 30 % of young camels die, while Moustafa et al. (2004) estimate that 23 % die. Diarrhea of various etiologies, particularly in young animals under six months of age, parasitosis, and respiratory diseases appear to be the main causes of camel mortality.

5.1. Blood biochemical parameters

5.1.1. Protein-energy parameters (blood glucose, total protein and urea)

The camel has an excellent ability to manage its protein-energy metabolism in a variety of feeding situations by mobilizing or storing its fat reserves humps, and its blood glucose level ranges between two extremes, 0.6 g/l and 1.4 g/l (Faye and Bengoumi, 2018). During the study, the average blood glucose level was 1.21 ± 0.04 g/1. This value is significantly higher than in other ruminants, such as cattle (0.42 to 0.74 g/l) (Kaneko et al., 2008). This value is comparable to that reported by Souilem et al. (1999) for Tunisia (1.22 g/l); Kelanemer et al. (2015) found a similar level of 1.23 g/l in Algeria. Faraz et al. (2021) found blood glucose levels of 1.36±0.8 g/l in adult, non-pregnant Pakistani camels reared under semi-intensive conditions. Blood glucose levels appeared to be affected by age, sex, and production status ($p \leq 0.01$) (1.6 g/l in young individuals vs. 0.73 g/l in adults). Abdalmula et al. (2019) in Libya, Yassin et al. (2015), and Ali et al. (2010) in Saudi Arabia, all reported lower blood glucose levels (0.71 ± 0.13 g/l).

However, El-Harairy et al. (2019) report a lower level (0.5 g/l). Total protein and urea levels in the blood are accurate indicators of nitrogen supply. The blood total protein level determined in this study was 63.87 ±3 g/1 and ranged from a low of 62 g/l in young animals to a high value of 65.25 g/1 in adult animals. Our findings are in agreement with those obtained by Kelanemer et al. (2015) and Faraz et al. (2021). The influence of age was not significant ($p > 0.05$), whereas sex and production status had a significant influence ($p \leq 0.001$). In contrast, El-Harairy et al. (2019) reported a higher value (90 g/l). Faye and Bengoumi (2018) describe the camel as an animal with a high capacity for recycling non-protein nitrogen (urea). We obtained an average urea value of around 487.6 ± 36 mg/1, with a minimum of 375.55 for young animals and a maximum of 492.6 mg/1 for adult animals. These values are also close to the values reported by Faraz et al. (2021), Abdalmula et al. (2019) in Libya, Kelanemer et al. (2015) in Algeria, Bengoumi (1992) in Morocco, Faye et al. (1995) in Morocco, Souilem et al. (1999) in Tunisia. Statistical analysis of the data revealed that age and sex had no effect on blood urea levels ($p \geq 0.05$), while production status had a significant

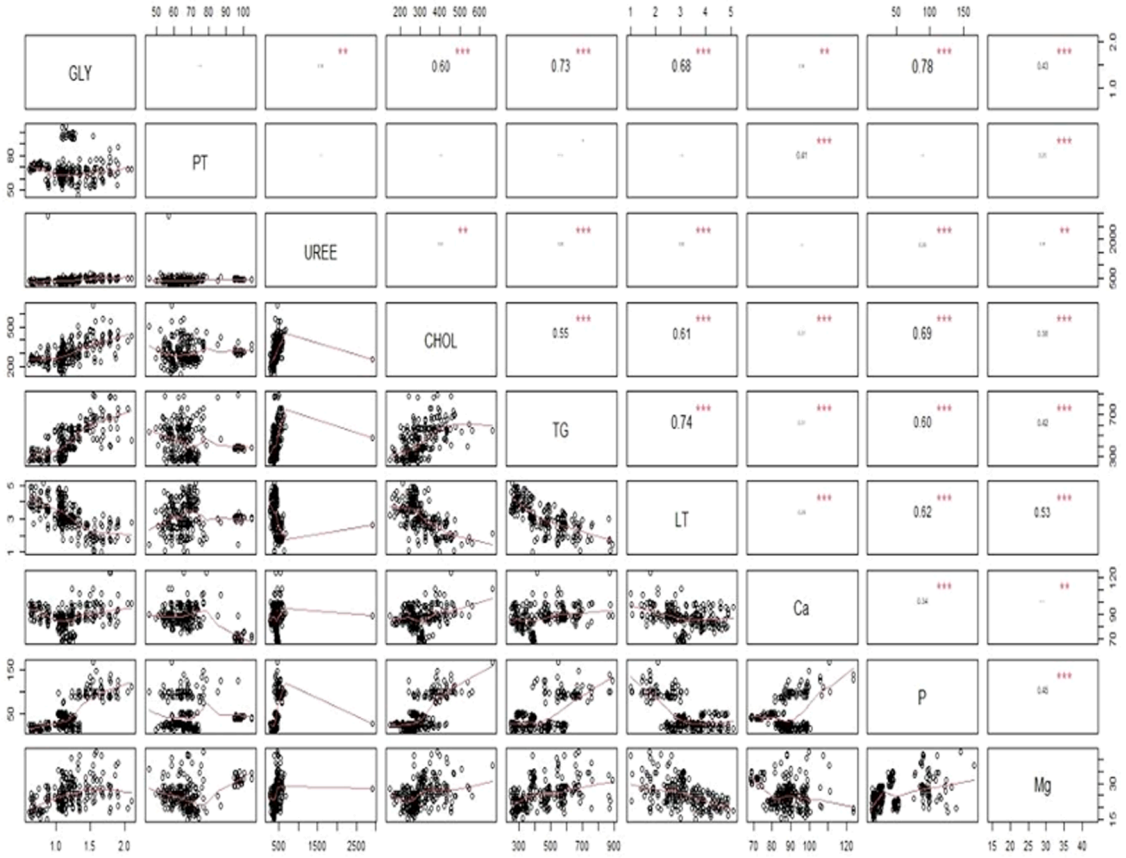

Fig. 2. Correlation between different biochemical parameters.

effect ($p \leq 0.01$) on urea levels. The effects of lactation and gestation on nitrogen mobilization could explain this. The nature and availability of the forage, particularly during the humid season when the diet is based on young grass rich in non-protein nitrogen and energy, in contrast to the dry season, when the diet is based on woody pastures poor in simple sugar and nitrogen, could explain the variation in the results found by the various authors. Overall, the different animal categories showed significant differences in glycemia $R^2 = 0.82$, but there were no differences in urea or total protein.

5.2. Lipid parameters

The majority of animal fat reserves consist of triglycerides. In the literature, values between 100 mg/l to 800 mg/l are given for camels (Faye and Bengoumi, 2018). The mean blood triglyceride level in blood in this study is around 487.66 ± 36 mg/1, with extreme values of 297.25 mg/1 in adult animals and 748.47 mg/1 in young animals. A comparison of the results reveals a significant difference ($p \leq 0.001$) between the three groups of animals. It should be noted that Faye et al. (1991) made the same observation. Neither furthermore, sex nor production status had any effect on triglyceride levels (Tables 5 and 6). Yassin et al. (2015) and Kelanemer et al. (2015) found similar results in the literature. Cholesterol is a precursor for the production of hormones. The cholesterol level in the blood of camels is between 180 and 1500 mg/l (Faye and Bengoumi, 2018).

Our results show that dromedary camels have a mean blood cholesterol level of around 318.7 ± 32 mg/1, with extreme values of 204.33 mg/1 in animals aged 12 to 24 months and 470.38 mg/1 in young animals under 4 months which is not statistically significant ($p \geq 0.05$). Similar findings were reported by El-Sayed (2020), Abdalmula et al. (2019), and Ali et al. (2008). In contrast, Faraz et al. (2020) found high cholesterol levels of 586.0 ± 45.4 mg/l and low triglyceride levels of 363.5 ± 49.3 mg/l. On the other hand, Ali et al. (2010) reported low values for both parameters, 235 ± 20 mg/l for cholesterol and 173 ± 13 mg/l for triglycerides. Concerning triglyceride levels, the sex and production status had no effect ($p \geq 0.05$).

Studies on total lipids in dromedaries have received little attention (Faye et al., 2018). Some authors reported a low average value between 1 and 2 g/l. Ali et al. (2018) reported a value of 1.04 ± 0.15 g/l, and Yagil and Berlyne (1976) found a value of 2 ± 0.4 g/l. However, other authors have reported higher values, such as Mohamed (2008), who reported an average value of 6.7 ± 1.2 g/l, and Adel and El-Matwaly (2012), who found values between 8.7 g/l to 9.3 g/l. In this study, the mean value was 3 ± 0.31 g/1. According to the statistical analysis, age had a highly significant effect on triglyceride and cholesterol levels. Sex, on the other hand, had did not effect on total lipids. A comparison of the mean values of the three parameters shows that sex has no influence. Our findings show that reproductive status has no effect on lipid parameters, which is consistent with the findings of Saeed and Khan (2012). The results also indicate that not all animal classes have different cholesterol levels ($R^2 = 0.58$).

5.3. Mineral status parameters

Calcium is the most stable constituent of blood plasma. In an adult animal, the blood level in plasma is around 100 mg/1 (Faye and Bengoumi, 2018). Calcium is the most abundant mineral in the body (1–2 % of body weight) and a major component of bone. Bresson and Mariotti (2016) explain that it regulates muscle contraction, nerve transmission, vascular function, and blood coagulation. The average calcium value reported in this study is 87.45 ± 2.7 mg/1, with a minimum of 82.5 mg/1 and a maximum of 94 mg/1. This small variation between these extremes attests to the parameter's stability. The same result was reported in previous reports (Abdalmula et al., 2019; Ali et al., 2018,

2010; El-Sayed, 2020; Kelanemer et al., 2015).

Phosphorus is involved in the storage and transport of enrgy and regulates the body's acid-base balance. Since calcium-regulating hormones such as parathyroid hormone (PTH) and 1,25-dihydroxycholecalciferol (1,25(OH)2D) act at the bone, intestinal, and renal levels, phosphorus homeostasis is closely linked to calcium homeostasis (Bresson and Mariotti, 2016). The results indicate that the mean phosphatemia value is 46.5 mg/1, with extreme values varying widely (15.81 to 113.38 mg/1). Faraz et al. (2021) and Abdalmula et al. (2019) reported similar results. In contrast, Ali et al. (2018, 2010) observed higher values (67 ± 3 mg/l). El-Sayed (2020) found lower values in adult females at the end of lactation.

Magnesium is required for the proper functioning of many enzymes and is involved in various metabolic reactions, including ATP formation and the transmission of nerve impulses (Bresson and Mariotti, 2016). The average magnesium level was 23.47 mg/l, with a minimum value of 21.72 mg/l in animals aged more than 24 months and a maximum value of 24.93 mg/l in animals aged 12 to 24 months. Our results are similar to the value of 25.86 mg/l reported by Abdalmula et al. (2023) and lower than value of 39.02 mg/l reported by El-Sayed (2020). The grass-based diet and the study season could explain this variation in results.

The comparison of the mean values of the three minerals reveals the influence of age on the blood calcium and phosphorus levels, while other autheurs have also attributed this influence to age and sex (Bengoumi, 1992; Faye and Mulato, 1991). The milk diet for young subjects could explain the age effect highlighted in this study. The young animals have very high calcium assimilation after a milk diet ($p \leq 0.001$), while age has no effect on blood magnesium levels. Sex appears to have an effect on phosphatemia, but has no effect on blood calcium or magnesium levels. Faye and Mulato (1991) made the same observation in relation to production status. In addition, the results show that production status has a significant ($p < 0.01$) effect on blood calcium and phosphorus levels, but no effect on magnesium levels ($p \geq 0.05$). Ebissy et al. (2019) reported similar results and found that females under production conditions have lower blood calcium and phosphorus levels in response to the physiological demands of pregnancy and lactation. Calcium and magnesium levels differed in all animal categories, which is confirmed by the coefficient of determination R^2 between the different biochemical parameters of 0.65 and 0.51. However, no difference in blood phosphorus levels was constated in this study.

6. Conclusions

The results of the current study provide values for the reproductive and hematobiochemical parameters of dromedaries in Algeria. These values can be used by local and North African breeders and clinicians to improve production and better utilise this species, which is highly adapted to regions with extreme climatic conditions. The reproductive parameters obtained in Algerian dromedaries seem to reflect a low performance of this species, although the fact that the biochemical balance values were within the ranges reported in the literature for camels indicates a normal health status of these animals. Several factors appear to contribute to this result (the breeding system, feed, climate change, etc.). In view of this situation, considerable efforts are needed in this area in the future. In our country, serious, in-depth studies of this animal in its natural environment and under actual breeding conditions should be at the center of scientific research.

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Funding

This research received no external funding

Institutional review board statement

During this study, no invasive procedure was performed during the sampling

CRediT authorship contribution statement

Rabah Kelanemer: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Djallel Adel:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Bachir Medrouh:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Conceptualization. **Redha Belala:** Writing – review & editing, Validation, Resources, Methodology, Investigation, Data curation. **Sabrina Sellali:** Writing – review & editing, Visualization, Methodology. **Amina Saidi:** Writing – review & editing, Validation, Resources, Methodology, Data curation. **Ammar Kalem:** Writing – review & editing, Validation. **Yasmine Rahmoune:** Writing – review & editing, Visualization, Resources. **Naima Dellal:** Writing – review & editing, Validation, Resources, Investigation. **Said Fettata:** Writing – review & editing, Validation, Resources, Investigation. **Nassim Moula:** Writing – review & editing, Software, Methodology, Conceptualization. **Hocine Ziam:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Conceptualization.

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.

Acknowledgments

The authors are grateful to Mr. Ali Rabahi, director of the High Commission for Steppe Development, and Abedelwaheb Benyahia, director of the Agropastoralism Research Center, for their assistance. And Abedelkader Touisset, president of the camel industry's interprofessional council.

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