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Changes of Hematology Profile, Blood Biochemistry and Hormonal Functions of Dromedary She-Camels under the Northwest Coastal Desert in Egypt

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Abstract

THE camel is a versatile livestock specie that holds significant economic value. In this study, the hematology profile, blood biochemistry and hormonal functions of dromedary she-camels in the northwest coastal desert of Egypt were assessed. Blood samples were collected from twelve adult dromedary she-camels during different seasons. The rectal temperature was higher in summer, while respiration rate was higher in winter and spring than in other seasons ($P<0.05$). Packed cell volume and mean corpuscular volume were the highest ($P<0.05$) in summer. The AST activity was the highest in spring, while ALT activity increased in autumn compared with other seasons ($P<0.01$). The highest lymphocytes and neutrophils were noticed in summer and spring, respectively. Albumin was higher ($P<0.01$) in winter and spring than in summer and autumn. The greatest level of cortisol hormone was observed during spring season ($P<0.0001$). Summer season produced higher levels of T3 compared to other seasons ($P<0.0001$), while summer and spring recorded the greatest levels of T4 when compared to other seasons. Collectively, it can be observed that season had a significant effect on blood profile, biochemistry, and hormones, affecting the reproductive patterns of dromedary she-camels in the northwest coastal desert of Egypt.

Keywords: Season, Dromedary She-Camels, Hematology, Blood Biochemistry, Hormonal Profile.

Introduction

Dromedary camel is distinguished by its unique ability to survive in harsh conditions in arid desert areas. This animal has a phenomenal ability to tolerate high heat and withstand water scarcity, periods of severe drought, and long periods of feed shortages. Due to its remarkable adaptability and distinctive anatomical structure of vital organs, it is capable of withstanding harsh conditions and resuming its performance when these conditions are overcome [1]. Therefore, camels are superior in their suitability to desert environments compared to other large ruminants such as sheep and goats [2]. In Egypt, the majority of camels are raised under a nomadic husbandry system as dual-purpose animals mainly for meat and to a lesser extent for dairy production [3,4]. Traditionally, camels were used in transportation in Nile Delta villages and urban regions besides tourism aspects. Recently the utilization of its hair and leather has started to become of interest [5,6].

The importance of these animals should be highlighted given the increasing rate of global warming, the possibility of desertification of vast areas, and the exacerbation of food shortages around the world. Raising camels may be a solution to confront and solve these problems in the future [7,8]. Camels adapt well to seasonal fluctuations in ambient climatic conditions by modifying their physiological responses [9,10]. They can store body heat during days of high ambient temperature and dissipate excess heat during cold nights as a

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mechanism of water conservation [1]. Comparing blood values under different management systems is important as they reflect the health, physiological status, and productivity of camels [11-13]. Therefore, both physiological and hematological parameters may help in assessing and predicting how well camels perform and adapt to certain environments. Despite the increasing interest in camel research in recent decades, results have shown regional differences [14] based on climatic conditions, food availability, and stress susceptibility in each region [15,16]. Additionally, the effect of seasonal fluctuations in climatic conditions within a specific region has been confirmed [9,11,13]. This study aims to assess the effects of seasonal fluctuations during different seasons on the physiological response, hematology, blood biochemistry, and adrenal and thyroid functions of dromedary she-camels kept under a semi-intensive system in the semi-arid conditions of the northwest coastal desert belt in Egypt.

Material and Methods

This study was carried out at the Maryout Research Station "situated at a latitude of 30.99°N and a longitude of 29.78°E, with an altitude of 32 meters above sea level. It is located 35 km southwest of Alexandria city and represents the semi-arid desert conditions of the northwest coastal belt of Egypt.", affiliated with the Desert Research Center (DRC), Ministry of Agriculture and Land Reclamation, Egypt, in cooperation with the Animal Production Department, Faculty of Agriculture, Mansoura University, Egypt. The experiment lasted for four successive seasons, starting in the summer of 2020 (June) and ending in the spring of 2021 (May).

Meteorological data

Meteorological data, including the average ambient temperature (T_{av}, °C) and relative humidity (RH, %), were recorded daily by a data logger (HOBO Pro Ser. Onset, USA) throughout the experimental period. The Temperature-Humidity Index (THI) was calculated using the equation adopted by Habeeb et al. [17] as follows: THI (°C) = $T_{av} - 0.55 * (1 - (0.01 * RH) * (T_{av} - 14.5)$.

Animals and management

Twelve adult dromedary she-camels (non-pregnant and non-lactating) were used in this study. The camels were housed in semi-shaded open barns and fed a concentrate feed mixture (2.5 kg head^{-1} day^{-1}) consisting of 65% yellow corn, 20% wheat bran, 10% soybean meal, and 5% cottonseed meal, in addition to alfalfa hay (2.5 kg head-1 day -1) and rice straw (1 kg head^{-1} day^{-1}). The animals were allowed to free graze for 5 hours daily on the natural range of Atriplex sp. shrubs, Kochia indica, and Acacia trees. Fresh water was available twice a day during the experimental period.

Physiological response parameters

Measurements of rectal temperature (RT, ºC), skin temperature (ST, ºC) and respiration rate (RR, breaths/minute) were recorded monthly, and then the average of each season was calculated. RT was measured to the nearest 0.1 ºC using a clinical digital thermometer inserted into the rectum approximately two inches for 2 minutes. ST was measured by applying an infrared thermometer to a shaved clean small area (4x4 cm) at the last rib on the right side of each animal. RR was recorded by counting the frequency of flank movements per minute; a pair of inward and outward movements of the flank represented one breath. All possible precautions were taken into consideration to avoid the effect of disturbance and hyperactivity.

Blood sampling

Blood sampling was conducted in the summer (July 2020), autumn (October 2020), winter (January 2021), and spring (April 2021) seasons via jugular vein puncture using clinical needles. The number of samples in each season represented the total population of the experimental animals (n=12). About 10 ml of blood was collected in vacutainers containing ethylene diamine tetra acetic acid (EDTA), as an anticoagulant. Whole blood samples were taken for hematological parameters, and then the blood samples were centrifuged at 2000 rpm for 10 minutes to isolate plasma, then stored in glass vials at -20°C for biochemical analyses.

Hematological parameters

A complete blood picture, including total erythrocyte count (TEC), hemoglobin concentration (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), total leukocyte count (TLC), and leukocyte profile representing percentages of lymphocytes, monocytes, eosinophils, and basophils, was also obtained using the Mindray BC-3200 instrument.

Biochemical analysis

Biochemical analyses in blood plasma were performed using a fully automated chemistry analyzer (Bio-Systems A25, Spain). Plasma total proteins (TP) and albumin (ALB) were assessed using Micro BCA and BCG kits (MP Bio-medicals, USA). Globulin (GLB) was calculated by subtraction, and then the albumin to globulin ratio (AGR) was determined. The activity of aspartate aminotransferase (AST) and alanine aminotransferase (ALT), as indicators of liver function, was measured using the revised spectrophotometric method [18]. Urea and creatinine concentrations, as evidence of kidney function, were estimated. Urea was determined according to the method of Tiffany et al. [19]. and creatinine was kinetically measured based on the Jaffe reaction with alkaline picrate. Kits for these determinations were sourced from BIOLABO (France). Concentrations of plasma thyroxine (T4), triiodothyronine (T3), and cortisol were measured using a microplate enzyme immunoassay with a semi-automated Elisa system (Teco, USA) according to Lopez et al. [20].

Statistical analysis

A Shapiro-Wilk test was conducted to check for normality. The significant effects of the treatments were examined by One-way ANOVA (PROC ANOVA; SAS Institute Inc., 2012). The level of statistical significance was set at α = 0.05. The following mathematical model was applied to analyze all measurements: $Y_{ij} = \mu + TR_{Ti} + e_{ij}$.

Where Y_{ij} = Observations, μ = Overall mean, TR_{Ti} = effect of the season (i, 1 to 4), e_{ij} = random error. Results were expressed as mean ±SE. Tukeys' test was used at $P<0.05$ to perform pairwise comparisons between means in case a significant effect was detected.

Results and Discussion

Meteorological data

Fig. 1 shows seasonal changes in meteorological values. The average of ambient temperature (T_{av}, °C) and temperature-humidity index were the highest in summer, moderate in autumn and spring, and the lowest in winter. However, relative humidity (RH%) was the highest in autumn, decreased to be moderate in winter and the lowest in spring, then increased in summer but was lower than its values in autumn. To clarify the extent of camels' exposure to heat stress during the four successive seasons, the temperature humidity index (THI) was calculated, being the highest at 27.27 in summer, moderate in autumn and spring (24.6 and 23.1), and the lowest (18.30) in winter. Depending on the variance in THI values, there are specific extents through which the animal's condition can be determined in terms of whether it is susceptible to stress. According to Tulu, et al. [21], THI < 27.8 indicates the absence of heat stress, 27.8–28.9 indicates moderate heat stress, 28.9– 30.0 indicates severe heat stress, and ≥ 30.0 indicates very severe heat stress. Therefore, the results of THI values in the current study revealed that camels were not susceptible to heat stress during different study seasons, as they were outside the limits of severe heat stress.

Physiological responses

Season showed a significant effect on both rectal temperature (RT) and respiratory rate (RR), but skin temperature (ST) was not significantly affected by season (Table 1). RT was higher ($P<0.05$) in summer than in other seasons. RR was higher ($P<0.05$) in winter and spring than in summer and autumn. These results indicate that RT was the highest ($P<0.05$) in summer compared to other seasons, coinciding with the highest values of THI recorded in summer. These results are consistent with those reported in farm and freely grazing dromedary camels [9,21]. Elevating body core temperature might be an effective mechanism in hot conditions by obstructing the transmission of ambient heat into the animal's body through reducing the range between ambient temperature and body core temperature. It is interesting to note that the significant differences in RT in summer compared to other seasons were slight. In dehydrated camels, exposure to heat stress develops a heat tolerance mechanism that depends on elevating body temperature by 6-7 °C [22]. The retained heat due to this mechanism dissipates from the camel body and releases to the ambient air via radiation at night without using water to avoid permanent overheating [1,23]. The reduction in RR in summer and autumn compared to winter and spring is within the normal range of RR in camels [24]. Only under extreme exposure to hot climate, camels' resort to increase their breathing rates. An acute increase in body temperature from 35 to 41 °C was found to increase camel's RR by about 70 to 80 breaths per minute to prevent brain overheating [25,26]. The magnitude of difference accounted in RT between summer and other seasons was slight (0.3-0.5 °C). Therefore, it is likely that the respiratory rate did not increase during the summer or spring, as the rise in ambient temperature did not lead to a sharp increase in body temperature.

Contrary to the current findings, there was an opposite seasonal rhythm of RR fluctuations in one-humped camels, where it was lower in cold climates than in hot climates. This contradiction between the results can be attributed to the higher THI (higher T_{av} and RH) recorded in spring and summer than in autumn and winter seasons (Fig. 1). In accordance with our results, Nissim Silanikove [27] revealed that the efficiency of evaporative cooling declines with higher percentages of relative humidity. As a phenomenal desert animal, camels might decrease their rate of respiration in hot climates to optimize water balance and conserve their body fluids and metabolic energy that may be lost by hyper-respiration rates [1,28]. In the hot summer season, with elevating RT and decreasing RR, camels optimize their water turnover rate to minimize water loss [28]. Despite their large body size, camels have the lowest water turnover rate (38-76 ml kg^{-1} d^{-1}) compared to sheep (62-127 ml kg^{-1} d^{-1}) and goats

(76-196 ml kg^{-1} d^{-1}), which contributes to decreasing water loss and optimizing the capacity of heat tolerance [29].

The absence of significant differences among different seasons may indicate the efficiency of camels in thermoregulation by raising body temperature and reducing breathing rate without the need to readjust skin temperature, as long as they are not exposed to heat stress. In this context, Kuhnen and Jessen [30] revealed an inverse relationship between the metabolic rate and skin temperature of goats during the thermoregulation of their body temperature. Therefore, it may also indicate the superiority of one-humped camels over other desert ruminants in maintaining their metabolic rate and conserving metabolic energy by maintaining a constant skin temperature.

Hematological indices

Except for the total erythrocyte count (TEC), all estimated blood parameters in the current study showed significant variations due to the season (Table 2). The total erythrocyte count (TEC) was almost constant (2.9 x 10^6 ml^{-1}) in summer, autumn, and winter, although it showed a slight decline (2.6 x 10^6 ml^{-1}) in spring. These values were consistent with those reported by one author [11] but were obviously lower than those reported by other authors [24,31,32]. Camel had a wide range of TEC [33] and several reports did not find any seasonal variation in TEC [13,34]. However, opposite trends were reported by other authors [15,24,31,32].

Hemoglobin concentration did not exhibit any significant variations due to shifting between summer, autumn, and winter, but decreased ($P<0.05$) to the minimum level in spring. The relatively constant level of hemoglobin during three consecutive seasons may reflect the efficiency and adequacy of the nutritional status which helped maintain this level without significant changes [11,24]. Decreasing hemoglobin concentration in spring may be related to the impact of elevated ambient temperature, solar radiation and THI on the camel's appetite and physiological responses [13,35,36].

Packed cell volume was the highest ($P<0.05$) in summer, crucially in autumn and winter then raised ($P<0.05$) again in spring. This trend is in agreement with the findings of several authors [16,37], who reported a decrease in packed cell volume during cold seasons compared with hot seasons. An opposite trend was reported by Babeker et al. [11], who reported a decreased PCV during hot summer and attributed their results to either ambient temperature or state of hydration. Higher PCV percent during summer might be attributed to the higher tissue's requirements of oxygen that stimulate hematopoiesis to meet these requirements in addition to the greater erythrocyte's mobilization from the spleen, lungs, and liver that may be stimulated by heat stress ion, which is another explanation of PCV increment in hot weather [38]. Higher PCV values would enhance blood oxygen fixation to insure better tissue oxygenation in hot climates [16]. Mean corpuscular volume (MCV) was the highest in summer, moderate in autumn and winter, and the lowest in spring ($P<0.05$). The result of this study was in coincidence with some authors [39, 31], who reported significantly higher MCV values in hot than in cold seasons. Coincidentally, a significantly higher MCV in summer than in autumn [34]. Oppositely, our results were in discrepancy with the results obtained many reports [11,15,40], who reported lower MCV in hot than in cold seasons, while other authors [3,24] reported that the MCV did not vary due to ambient seasonal climates. Generally, MCV followed the same trend of PCV in summer. This was in accordance with [41] who stated that changes in PCV would be mainly related to that of their corresponding MCV values. The erythrocytes of the dromedary are flat with high resilience to change their shapes. However, hyper-watering and quick rehydration cause a dramatic swelling of these cells that become circular and gain in volume [42]. Although the camel has the capacity to drink a large amount of water without over hydration [28], this may influence the hypo- and hyper-tenacity of its erythrocytes [11]. Increased water intake as a reflection of the higher ambient temperature in summer leads to higher swelling rates of erythrocytes and increases their mean volumes [16]. Therefore, higher PCV and MCV in summer might be referred to the higher drinking rates during the hot season.

Mean corpuscular hemoglobin (MCH) was highest in autumn, moderate in winter and summer, then decreased to the lowest values in spring. In accordance with the present results, some authors [15, 40, 43] reported a seasonal effect on the MCH mean value. However, other reports [13, 24, 31] found no seasonal effect on MCH. In mild and cold climates, camels can go several months without drinking and may refuse offered water [25]. This behavior may lead to the concentration of blood constituents. Therefore, the higher MCH values in autumn and winter might be due to the voluntary reduction in drinking rate resulting in a higher concentration of erythrocyte constituents. In contrast, the lower MCH values in summer and spring could be explained by the capacity of erythrocytes to swell with water when camels increase their voluntary drinking rates, diluting their erythrocyte constituents during these seasons [11, 44]. Mean corpuscular hemoglobin concentration (MCHC) did not vary significantly between summer and autumn, being lower, and between winter and spring, being higher

(P < 0.05). It significantly increased (P < 0.01) in winter to more than two times its magnitude in autumn and maintained its level in spring. Compared to MCH, which quantifies the amount of hemoglobin per single red blood cell, MCHC indicates the amount of hemoglobin per unit volume of erythrocytes [44]. Considering the relative stability in total erythrocyte count (TEC) during the experiment, it is unlikely that the increased winter level of MCHC can be attributed to a possible erythropoiesis rate. Babeker et al. [11] revealed seasonal changes in MCHC in relation to variations in hemoglobin (Hb) and packed cell volume (PCV). Prolonged exposure to ambient temperatures below body temperature might cause autoimmune hemolytic anemia due to cold-reacting autoantibodies, with symptoms including a noticeable increase in MCHC levels that continue with continued exposure to cold [44]. Yagil et al. [42] revealed that relatively high MCHC in camel erythrocytes may enhance their resistance to hemolysis, which is an important adaptation to life in a desert environment. Seasonal variations in MCHC in dromedary camels have been previously mentioned by many authors [11, 13, 40].

Leukocyte count

The total leukocyte count did not show any significant differences in autumn, winter, and spring, but it was higher (P<0.05) than in summer (Fig. 2). This trend is consistent with the findings of different reports [13,24,31]. This trend may be attributed to the reduction in corticosteroid secretion induced by prolonged exposure to high ambient temperatures in summer [31]. Additionally, changes in blood volume due to altered water balance were considered as an effective factor on leukocyte concentration. Badawy et al. [31] revealed that lymphocytes were the predominant leukocytes in one-humped camels, with neutrophils being the next, which was typical of most other ruminants. Pronounced changes in lymphocyte proportion occurred with seasonal shifting. Lymphocytes showed the highest magnitude in summer, decreased in autumn, rose again in winter, and declined in spring, then increased in the following summer.

Proportions of different types of leukocytes (neutrophils, lymphocytes, monocytes, and eosinophils) revealed significant seasonal variations, as illustrated in Fig. 3. The highest frequency distribution was for lymphocytes in summer, autumn, and winter, and for neutrophils in spring. However, eosinophils represented the lowest frequency distribution in all seasons. Similarly, several reports indicated a significant effect of the season on various leukocyte fractions [11,40]. However, this result contradicted the findings of some authors [13,34]. Lymphocytes and neutrophils constituted the two largest sets of immune cells. Coincidentally, lymphocytes were the predominant leukocytes in one-humped camels, with neutrophils being the next, which was typical of most other ruminants [32,34,41]. Pronounced changes in lymphocyte proportion occurred with seasonal shifting. Lymphocytes showed the highest magnitude in summer, decreased in autumn, rose again in winter, and declined in spring, then increased in the following summer.

Ulmasov, et al. [45] suggested that the summer increase in camel lymphocytes is a result of the strong production of heat shock proteins that enhance the heat tolerance of camel blood cells. The decrease in lymphocyte proportion appears to have been in favor of the increase observed in the proportion of neutrophils in all seasons. A similar trend of variance was reported [46]. Coincidently, Lin et al. [47] demonstrated that lymphocytes and neutrophils represent the two largest sets of immune cells. Other authors [31] reported a higher proportion of neutrophils in summer compared with winter. Yousif et al. [48] referred to such elevated levels of neutrophils during summer in camel blood as being due to exposure to dusty, polluted conditions under warm environmental conditions.

The ratio between neutrophils and lymphocytes proportions (NLR) was higher (P<0.01) in autumn compared with its values in summer and winter, and was the highest (P<0.05) in spring (Fig. 4). This was associated with changes in the proportions of both neutrophils and lymphocytes in conjunction with weather fluctuations in the spring and autumn seasons, where the percentage of neutrophil cells increased at the expense of the percentage of lymphocytes. NLR increased (P<0.01) in autumn to more than two times its summer value. This increase was followed by a marked decline (P<0.01) in winter, then a sharp increase (P<0.01) in spring to about five times its winter level. The elevated NLR during autumn might be a result of its coincidence with the beginning of the seasonal rut, which is accompanied by an increase in the number of neutrophils and a relative stability in the number of lymphocytes [34]. In contrast, the massive elevation in NLR during spring may be due to a higher lymphocyte apoptotic rate, which is accompanied by increased neutrophil synthesis as an innate immune mechanism to confront temperature fluctuations, drought, and air dust pollution [46]. Clinical studies have suggested that NLR may serve as a useful biomarker of disease due to its crucial role in inflammatory response, disease progression, and prediction of physiological efficiency [34,47]. It is a novel hematological parameter for systemic inflammation and stress, as it directly reflects the dynamic relationship between innate (neutrophils) and adaptive cellular immune response (lymphocytes) during illness and various stress states. Moreover, NLR is a very sensitive indicator of infection, inflammation, and sepsis, as validated in numerous studies [49].

Biochemical indices

No significant seasonal differences were observed in the concentrations of total protein (TP), except for the autumn, where TP concentration showed the lowest ($P<0.05$) values. The highest TP values were recorded in winter but did not differ significantly from that in autumn and spring (Fig. 5). Although the difference was not significant, TP showed a lower concentration in summer than that in winter and spring. Coincidentally, Ghosal et al. [50] reported higher levels of TP in winter than in summer in Indian camels. Albumin was higher ($P<0.01$) in winter and spring than in summer and autumn. On the other hand, globulin concentration showed a seasonal rhythm of variance like that of TP concentration. Results showed a marked decline ($P<0.01$) in albumin concentration in autumn by about 59% of its summer value. This decrease in the globulin level was not accompanied by a similar decrease in TP and albumin concentrations, reflecting a higher ($P<0.01$) albumin to globulin ratio (AGR) in autumn. Increasing levels of TP and albumin may indicate an improvement in pasture quality due to rainfall and vegetation regeneration in winter and spring seasons. Similarly, higher protein concentration in the serum of dromedaries during the rainy season [50]. Amin et al. [15] and Islam et al. [51] detected differences between the dry and green seasons in blood content of TP. Also, Martín-Barrasa et al. [10] explained that low albumin levels may result from malnutrition. The start of the rut season in autumn may also contribute to these results [46]. On the other hand, Mohamed et al. [52] reported a reduction in albumin concentration during a hot, dry environment without any effect on mean TP concentration in dromedaries, which contrasts with our results. Also, higher concentrations of TP, albumin, and globulin during summer and autumn than in spring and winter were reported [31,35].

Liver and kidney function markers

Season had a significant ($P<0.01$) effect on the activity of AST and ALT, which are markers of liver function and tissue damage (Table 3). AST activity was higher in spring than in other seasons ($P<0.01$), while ALT activity increased in autumn compared with other seasons ($P<0.01$). These values are within the normal range of 84.1-161.8 IU L^{-1} for AST and 7.1-21.5 IU L^{-1} for ALT [51], indicating normal liver function and no pathological effects in different seasons. Incidence of liver malfunction and/or tissue damage causes these enzymes to leak into the bloodstream and increases their concentration [53]. Additionally, it may indicate the high adaptability of camels to fluctuations in environmental conditions. Accordingly, the significant seasonal effects on AST and ALT activity were previously mentioned by other authors. In this context, AST and ALT activities were significantly higher in winter than in summer [54]. They attributed this difference to the cold stress that may induce more oxidant stress. Conversely, AST and ALT activities were significantly higher in summer than in winter as affected by heat stress [31,55]. Therefore, the current results may indicate that liver function was not extremely affected by seasonal climatic changes. Changes in urea and creatinine concentrations (Table 4) in different seasons revealed a significant seasonal effect on kidney function. Plasma urea concentration did not differ between summer and autumn, showing the lowest levels. Urea levels increased ($P<0.01$) in winter and again in spring to reach their maximum. This trend coincided with the findings of Aichouni et al. [40]. Generally, uremia reflects the complete or partial inability of the kidney to eliminate waste, including urea. It could be caused by lower infusion and glomerular filtration rates that accompany higher metabolic activity [55], although it may also be caused by reduced water intake and dehydration [31,32]

Adversely, the creatinine level was highest in autumn, moderate in summer, and the lowest in winter and spring ($P<0.05$) [31]. The highest creatinine level observed in autumn coincided with the finding of higher metabolic activity during this season, during which sexual activity was at its maximum. It may also reflect the dietary conditions of the animals included in this study. Similarly, Aichouni et al. [40] attributed the higher concentration of camel's blood creatinine during the wet season to the higher consumption of dietary protein.

Hormonal profile during different seasons

As reported in Table 4, season exhibited significant effects on blood hormone profile ($p<0.0001$). The greatest level of cortisol hormone was observed during spring season, while the lowest was noticed in winter season ($p<0.0001$). Summer and autumn had similar results for cortisol ($p>0.05$). Summer season produced higher levels of T3 compared to other season ($p<0.0001$), while both season (summer and spring) recorded the greatest levels of T4 when compared to other season. The activities of thyroid hormones in the bloodstream are primarily influenced by several factors such as the overall metabolic rate, seasonal variations, and water availability. It’s well known that the seasonal breeders for camels with the highest breeding activity observed during the winter and spring seasons [56]. A study [57] found that non-rutting male camels, which are not actively engaged in mating behavior, have higher serum concentrations of thyroid hormones compared to rutting camels. In our own research, we observed that the serum concentrations of thyroid hormones in camels were higher during summer compared to winter. Interestingly, a study by

Nazifi et al. [35] showed contrasting results, indicating that serum concentrations of thyroid hormones in dromedary camels were higher during summer compared to winter as indicated in our current research. This discrepancy suggests that there may be variations in thyroid hormone levels among different populations of camels or in different environmental conditions. In contrast to camels, studies on other animals have shown that serum concentrations of thyroid hormones are higher during winter compared to summer [58]. It is believed that cold temperatures stimulate the secretion of thyrotrophic hormone, leading to increased serum levels of thyroid hormones. Khanna, et al. [59] reported that camel thyroid function is inhibited during summer due to dehydration. This inhibition helps in conserving body water by reducing pulmonary water loss and lowering the basic metabolism. Similarly, [59] found that T4 levels gradually decreased in dehydrated dromedary camels during summer but increased after rehydration. In winter, T4 levels increased in dehydrated camels.

Seasonal variations can have an impact on cortisol hormone levels in camels. Cortisol is a hormone that is associated with the stress response and plays a crucial role in regulating various physiological processes in animals [60]. The reduced environmental stress in winter can lower cortisol levels in camels. They experience less physiological strain and have better access to food and water resources. Understanding the seasonal variations in cortisol levels in camels can provide insights into their physiological responses to environmental conditions and help inform management practices to support their well-being and stress management.

Conclusions

The results indicated that the moderate weather conditions in the desert of the northwestern coastal belt of Egypt are suitable for raising camels under semi-intensive systems. The physiological responses and changes in the blood parameters studied showed moderate levels of change, indicating that camels were not exposed to severe levels of climatic stressors during the different seasons in that area. Future studies are needed to evaluate the productivity and performance rates of dromedary camels in that region to optimize the benefits of dromedary camel raising.

Acknowledgments

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Conflicts of interest

The authors declared no competing interests.

Funding statement

Not applicable.

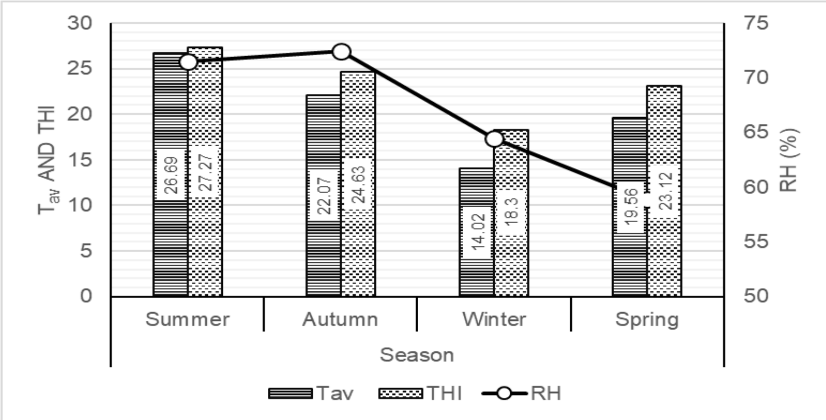

Fig. 1. Average ambient temperature (T_{av}, °C), relative humidity (RH, %) and temperature-humidity index (THI).

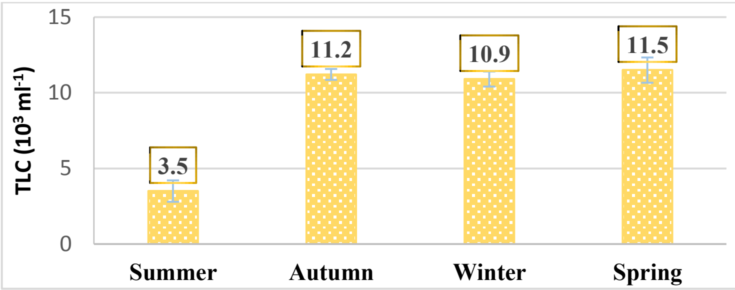

Fig. 2. Seasonal variations in total leukocytes count (TLC) of dromedary she- camels.

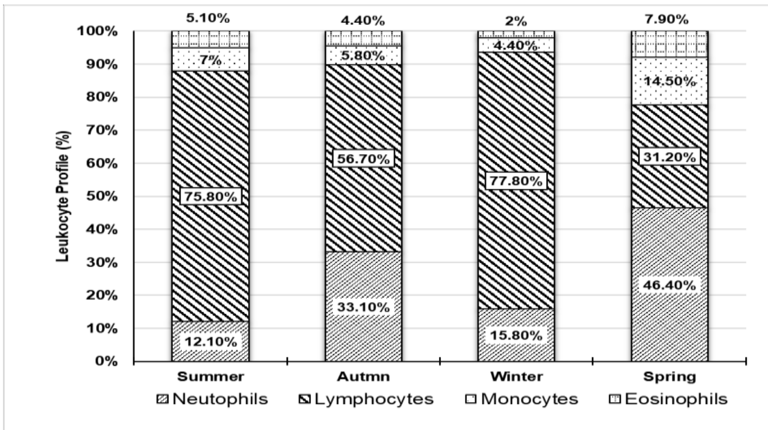

Fig. 3. Seasonal variations in leukocyte profile in blood of dromedary she-camels.

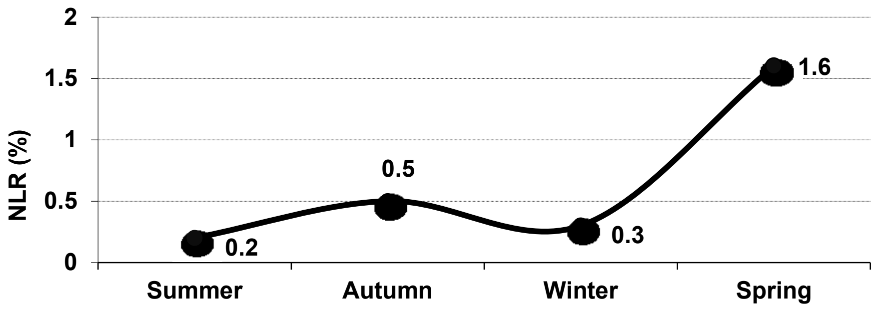

Fig. 4. Seasonal variations in neutrophils: leukocytes ratio (NLR) of dromedary she camels.

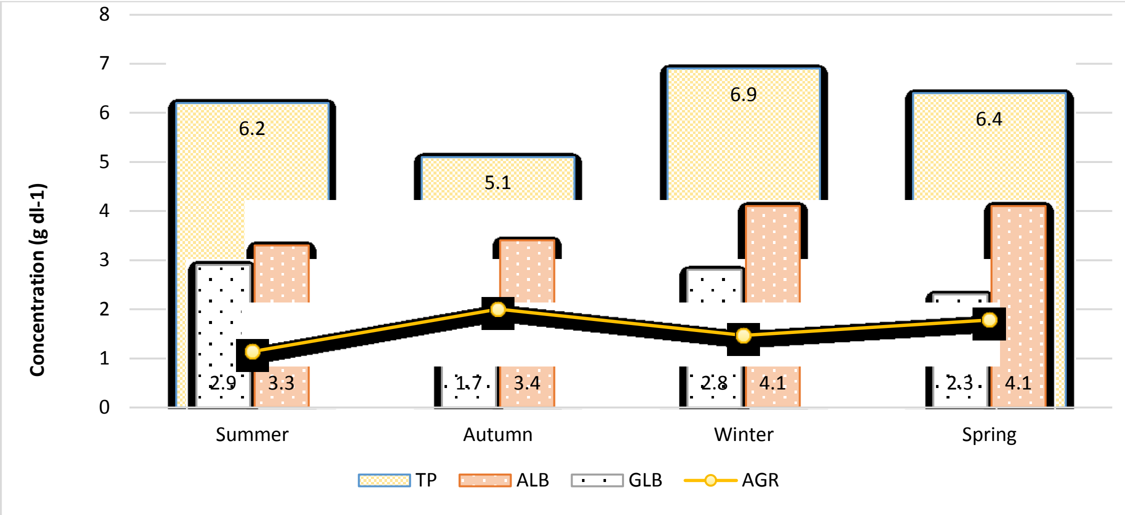

Fig. 5. Seasonal variations in total protein and their fractions in blood plasma of dromedary she-camels.

TABLE 1. Physiological responses of she-camels during different seasons.

Trait	Season				P value
	Summer	Autumn	Winter	Spring	
Rectal temperature (RT, °C)	37.9±0.07[a]	37.4±0.03[b]	37.4±0.03[b]	37.6±0.05[b]	<0.0001
Skin temperature (ST, °C)	35.8±0.10	35.9±0.10	35.8±0.14	36.2±0.11	0.130
Internal gradient RT-AT (°C)	2.1	1.5	1.6	1.4	-----
RR (breaths min^{-1})	12.7±0.24[b]	12.6±0.24[b]	13.6±0.26[a]	13.7±0.27[a]	0.003

[a-b] Significant differences at P<0.01 for different superscripts in the same row. RR: Respiration rate, min^{-1}.

TABLE 2. Hemoglobin concentration, total erythrocytes (TEC) count and erythrogram of she-camels during different seasons.

Item	Season				P value
	Summer	Autumn	Winter	Spring	
Hb, g dL^{-1}	11.0±0.51[a]	11.7±0.28[a]	12.0±0.43[a]	9.4±0.65[b]	0.005
PCV, %	19.0±1.05[a]	6.0±0.12[c]	7.4±0.32[c]	13.9±0.26[b]	<0.0001
TEC, 10^6 µL^{-1}	2.9±0.14	2.9±0.26	2.9±0.09	2.6±0.20	0.69
MCV, fL	107.9±4.47[a]	58.7±1.39[b]	51.0±0.36[bc]	45.1±0.71[c]	<0.0001
MCH, pg	38.2±1.77[bc]	44.0±0.41[a]	40.7±1.37[ab]	35.3±1.72[c]	0.001
MCHC, g dL^{-1}	35.6±1.31[b]	34.0±0.31[b]	78.0±3.54[a]	78.9±3.75[a]	<0.0001

[a-c] Significant differences at P<0.01 for different superscripts in the same row. Hb= Hemoglobin, PCV= paced cell volume, TEC= total erythrocytes, MCV= Mean corpuscular volume, MCH= Mean corpuscular hemoglobin, MCHC= Mean corpuscular hemoglobin concentration.

TABLE 3. Liver and kidney function markers of she-camels during different seasons.

Trait	Season				P value
	Summer	Autumn	Winter	Spring	
AST, IU L^{-1}	105.0±0.90[b]	102.4±4.13[b]	81.0±6.43[b]	132.1±10.21[a]	<0.0001
ALT, IU L^{-1}	18.6±1.32[b]	30.9±4.67[a]	15.9±1.10[b]	20.3±2.43[b]	0.001
Urea, mg dL^{-1}	34.1±1.09[c]	29.1±1.80[c]	51.4±1.96[b]	65.0±1.96[a]	<0.0001
Creatinine, mg dL^{-1}	1.2±0.07[b]	1.6±0.06[a]	0.9±0.05[c]	1.0±0.05[c]	<0.0001

[a-c] Significant differences at P<0.01 for different superscripts in the same row. AST= aspartate aminotransferase, ALT=alanine aminotransferase.

TABLE 4. Cortisol, Triiodothyronine, and Thyroxine changes in the serum of she-camels during different seasons

Treatment	Hormone profile		
	Cortisol (ng dl^{-1})	Triiodothyronine (T3, ng ml^{-1}/mL)	Thyroxine (T4, ng ml^{-1})
Summer	8.7±0.56[b]	1.4±0.09[a]	10.7±0.25[a]
Autumn	10.0±1.08[b]	0.9±0.06[b]	7.3±0.22[b]
Winter	0.7±0.10[c]	0.9±0.03[b]	8.5±0.50[b]
Spring	16.7±0.82[a]	1.1±0.03[b]	10.6±0.28[a]
P Value	<.0001	<.0001	<.0001

[a-c] Significant differences at P<0.01 for different superscripts in the same column.

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التغيرات في صورة الدم، وبعض المكونات البيو كيميائية ووظائف الهرمونات في إناث الجمال العربية تحت ظروف الصحراء الساحلية الشمالية الغربية في مصر

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المستخلص

يعد الجمل من أنواع الماشية المتنوعة التي لها قيمة اقتصادية كبيرة. في هذه الدراسة تم تقييم التغيرات في صورة الدم، وبعض المكونات البيو كيميائية ووظائف الهرمونات في إناث الجمال العربية تحت ظروف الصحراء الساحلية الشمالية الغربية في مصر. تم جمع عينات الدم من اثنتي عشرة ناقة بالغة خلال مواسم مختلفة. كانت درجة حرارة المستقيم أعلى في الصيف، بينما كان معدل التنفس أعلى في الشتاء والربيع مقارنة بالمواسم الأخرى .كانت نسبة الهيماتوكريت ومتوسط حجم الجسيمات هي الأعلى في الصيف. كان نشاط إنزيم ناقلة أمين الأسبارتات هو الأعلى في فصل الربيع، في حين زاد نشاط إنزيم ناقلة أمين الألانين في الخريف مقارنة بالمواسم الأخرى. ولوحظت أعلى نسبة من الخلايا الليمفاوية والمتعادلة في الصيف والربيع على التوالي. ومع ذلك، كانت الخلايا الحامضية أقل توزيع تكراري في جميع الفصول. كان الألبومين أعلى في الشتاء والربيع منه في الصيف والخريف. ولوحظ أعلى مستوى لهرمون الكورتيزول خلال فصل الربيع. كان مستوي هرمون التراي أيودوثيرونين في فصل الصيف أعلى مقارنة بالمواسم الأخرى، في حين سجل الصيف والربيع أعلى مستويات لهرمون الثيروكسين مقارنة بالمواسم الأخرى. ونستخلص من هذه النتائج أن الموسم كان له تأثير كبير على صورة الدم، والمكونات البيوكيميائية والهرمونات، مما قد يؤثر على أنماط التكاثر للإبل العربية تحت ظروف الصحراء الساحلية الشمالية الغربية في مصر.

الكلمات الدالة: الموسم والجمل العربي وصورة الدم والمكونات البيوكيميائية والهرمونات.