ORIGINAL RESEARCH

IMPACT OF HEAT STRESS ON PHYSIOLOGICAL, HEMATOLOGICAL, BIOCHEMICAL, ELECTROLYTIC, IMMUNOLOGIC AND ANTIOXIDANT PARAMETERS IN BALADI AND SHAMI GOATS OF EGYPT

F. E. Younis*

ABSTRACT

Livestock undergo various kinds of stresses that affect their productivity, out of which thermal stress is the most critical factor for desert animals, particularly goats grazed exclusively on range under extensive system. This study was conducted during summer season (June to September, 2016) on Baladi and Shami female goats of Egypt to assess the effect of heat stress on their physiological, biochemical, electrolytic, immunologic and antioxidant parameters. Forty female goats (twenty Baladi and twenty Shami goats) aged about 2-4 years and weighing 23.5 - 33.5 kg, were used for this experiment. Animals were divided into 4 groups (ten from each breed). One group in each breed (n=10) was exposed to solar radiation (experimental) in the courtyard, while the other group (unexposed) was kept in shade that served as control. The temperature-humidity index (THI), calculated on the basis of daily ambient temperature and relative humidity at 6 AM and at 2 PM indicated thermal stress in the afternoon (THI = 87.05) in exposed goats. Physiological parameters indicated that thermal stress significantly elevated ($P \leq 0.05$) coat temperature (CT), rectal temperature (RT), and respiration rate (RR). Breed difference was non-significant ($P \geq 0.05$). Hematological parameters indicated that thermal stress enhanced ($P \leq 0.05$) erythrocyte cell (RBC) counts, and depressed ($P \leq 0.05$) white blood cell (WBC) counts, hemoglobin (HGB), hematocrit (HCT) values and corpuscular hemoglobin concentration (MCHC). Breed differences were observed with respect to RBC, RNG, HGB, HCT and MCHC. Baladi had higher ($P \leq 0.05$) values of HGB, HCT and MCHC than Shami. Biochemical parameters indicated that the level of alanine amino transferase (ALT) increased ($P \leq 0.05$), while glucose, total lipids and cholesterol concentrations decreased ($P \leq 0.05$) due to thermal stress. Breed differences were observed with respect to urea, alkaline phosphatase, glucose, total protein and albumin. The levels were higher ($P \leq 0.05$) in Shami than in Baladi with respect to all the parameters except glucose, which was higher ($P \leq 0.05$) in Baladi than in Shami. Blood electrolytes indicated that Sodium (Na^+) concentration decreased ($P \leq 0.05$), while Potassium (K^+) and Chloride (Cl^-) concentrations increased ($P \leq 0.05$) due to thermal stress. Baladi had higher ($P \leq 0.05$) concentration of potassium and chloride than Shami. Immunological parameters indicated that level of cytokines, e.g., Interlukin-1 (IL-1) and Interlukin-6 (IL-6) increased ($P \leq 0.05$) due to thermal stress. The value of IL-1 was higher ($P \leq 0.05$) in Baladi than in Shami. The findings of this study have significant implications for goat breeders, e.g., Bedouins and nomadic goat rearers in protecting their animals from solar radiation (heat stress), to safeguard their health and productivity, while roaming incessantly in search of pastures in a thermally stressful desert environment.

KEY WORDS

Biochemicals, Electrolytes, Goats, Heat stress, Hematological, Immunological, Physiological

Author attribution: *Associate Professor of Animal Physiology, Department of Animal Physiology, Animal Production and Poultry Division, Desert Research Centre, Mataria, Cairo, Egypt. *Corresponding author (Email: alphayounis@gmail.com). Receipt: 02-Nov-19, Acceptance: 11-Dec-2019. pp. 21-39.

INTRODUCTION

Livestock undergo various kinds of stresses, e.g., chemical, physical, nutritional, and thermal stresses etc. Various factors that affect their productivity are enumerated as photoperiod, geographical location, age, breed, nutrient availability, water availability, management practices, and environmental conditions etc. (Khalifa, 2003; Sejian et al., 2012).

In the changing climatic scenario, thermal stress is the most crucial factor, which hampers livestock productivity. Adaptation is the morphological, anatomical, physiological and biochemical characteristics of an animal which promote welfare and favor survival in a specific environment. Stress represents the reaction of body to stimuli that disturb normal physiological equilibrium or homeostasis, often with detrimental effects (Khansari et al., 1990). According to Stott (1981), stress is the result of environmental forces continuously acting upon animals which disrupt homeostasis resulting in new adaptations that can be either detrimental or advantageous to the animal.

Among the stressors, heat stress has been of major concern in reducing animal's productivity in tropical, sub-tropical and arid areas (Silanikove et al., 1997). The degree to which an animal resists, there is change in body temperature, which varies with different species because of differences in their heat regulating mechanisms (Salah et al., 1995). Heat stress is an important determinant in the intensive animal production system, particularly in tropical and sub-tropical countries. In such regions, high ambient temperature is the major factor on animal mechanism and body temperature.

Ruminants do not maintain strict homeothermy under stress despite having a well-developed mechanism of thermoregulation (Tushar et al., 2017). Under thermal stress, a number of physiological and behavioral responses vary in intensity and duration in relation to the genetic make-up of the animal and environmental factors through the integration of many organs and systems, viz., behavioral, endocrine, cardio-respiratory and immune system (Altan et al., 2003).

Body temperature is regulated by cytokines, which are defined as regulatory proteins of polypeptides that are produced by immune cells in response to tissue injury, infection, stress, or inflammation (Younis, 2005; Younis & Abou El-Ezz, 2010).

IL-1β is a potent pro-inflammatory cytokine that acts as an endogenous pyrogen. It has been detected in CNS after injury to the brain or peripheral immune activation. IL-1β acts to suppress thyroid function by inhibiting iodide uptake and leading to decrease in the plasma levels of thyroxine (T4) and triiodothyronine (T3) that are known to play important roles in adjustment of mammals to environmental changes (Yousef and Johnson, 1975; Younis & Abou El-Ezz, 2010).

IL-6 acts as the principal regulator of the acute-phase protein response and stimulates the hypothalamic-pituitary-adrenal axis (HPA) and hypothalamic-pituitary-thyroid axis (HPT) that are known to play an important role in adjustment of mammals to environmental changes (Younis, 2005).

Indigenous breeds, particularly in tropical environment are considered to have some levels of resistance to high ambient temperature (Srikandakumar et al., 2003; Soleimani et al., 2011). However, it is not clear yet what is their physiological threshold for heat stress perception.

The current study aimed to investigate the effects of heat exposure magnitude on some physiological, hematological, biochemical and immune response in goats.

MATERIALS AND METHODS

Location of the experiment: This experiment was conducted at Ras-Sudr Research Station, belonging to Desert Research Center, Southern Sinai, Egypt, from June to September, 2016.

Treatments: Forty Baladi and Shami female goats aged 2-4 years and weighing 23.5 - 33.5 kg were used in the experiment. The goats (twenty Baladi and twenty Shami goats) were divided into 4 groups (10 of each). Animals were maintained in open pens (5.0m x 3.0m) with concrete floors in an open-sided barn for a 14-days adaptation period. The control group (unexposed) of animals was allowed to adapt in the sheltered pens, while the other group (exposed) of animals were let out of pens, and were directly exposed to the Sun. The animals were offered feed once a day at 8.00 a. m. Water was supplied ad-libitum. Ambient temperature, black body temperature and relative humidity were recorded daily at 6 a.m. and at 2 p.m. by thermometer. Temperature-humidity index (THI) was calculated as per Amundson et al. (2006) with the following formula:

$$\mathbf{THI = 0.8 \times AT\ ^{o}C + [(RH\ \% \div 100) \times (AT\ ^{o}C - 14.4)] + 46.6}$$

Blood collection and Estimation of Parameters: Blood was collected from jugular vein and placed in ice for estimation of RBC, total number of leukocytes using an automated instrument for complete blood counts (CBC) to determine WBCs, and relative and absolute number of lymphocytes, monocytes and granulocytes (Vet-Scan HM2™ Hematology System, Abaxis, Union City, CA).

The blood tubes were centrifuged at 4000 rpm for 15 minutes, and the plasma samples were stored in a freezer at -20^{o}C for subsequent biochemical analyses. Plasma samples were separated for biochemical analyses, e.g., aspartate amino transferase (AST), alanine amino transferase (ALT), alkaline phosphatase (ALP), glucose, cholesterol, urea, creatinine, triglycerides, total lipid, total protein and albumin using commercial colorimetric kits (Diagnostic Products Corporation, Los Angles, USA).

Globulin was calculated by subtracting concentration of albumin from that of total protein. Albumin/Globulin ratio (A/G ratio) was also estimated. Interleukin-6 (IL-6) was determined by using Quantikine IL-6 ELISA Kit (Hirano, 1998). Interleukin-1β (IL-1β) was determined by using Quantikine IL-β ELISA Kit (Martinon and Teschopp, 2007; Sims and Smith, 2010). Kits for IL-1β, and IL-6 were procured from Sigma (Aldrich-Sigma Company, CA, USA).

The antioxidants were measured colorimetrically. Malondialdehyde (MDA) was measured as described by Ohkawa et al. (1979), in which MDA reacts directly with thiobarbituric acid at optimum pH (3.5) to produce a red color that was measured spectrophotometrically.

Assessment of Physiological parameters: A digital thermometer was used for measuring rectal temperature. Coat and skin temperatures were measured using a non-contact infrared thermometer. Respiration rate was recorded by observing the flank movement.

Statistical Analysis: The data were analysed by least squares analysis of variance to obtain least squares means ± standard error of the mean. Duncan's multiple range test was used to assess the significance of differences between means. All analyses were performed with the aid of the GLM procedure of SAS software (SASI, 2004).

RESULTS AND DISCUSSION

Climatic condition: Ambient temperature (AT), relative humidity (RH) and temperature-humidity index (THI) at 06:00 am and 02:00 pm (time of physiological responses) throughout the experimental period are shown in Table 1.

Table 1: Diurnal pattern of the average climatic data during the experimental period

Climatic parameters	Un-Exposed		Exposed	
	6 a.m.	2 p.m.	6 a.m.	2 p.m.
Ambient Temperature (^{o}C)	28	37	28	40
Relative Humidity (%)	62	38	61	33
Temperature-Humidity Index	77.59	84.88	77.45	87.05

The data revealed that AT (40°C and 37°C) and THI (87.05 and 84.88) at 6 am and 2 pm, respectively, were higher in exposed groups than in control ones, while RH was lower in the afternoon (2 p.m.) than in morning (6 a. m.) in both control (38 vs. 62) and experimental (33 vs. 61) groups. It was observed that both the exposed and unexposed goats were under moderate heat stress during afternoon (THI: 87.05 vs. 84.88) and under mild heat stress in the morning (THI: 77.45 vs. 77.59).

Earlier studies have indicated that thermo-neutral zone is about 12–24°C for goats in the hot regions of the world (Nikitchenko et al., 1988; Mishra, 2009). Heat stress occurs due to imbalance between heat production within the body and its dissipation. In response to stress, animals set physical, biochemical and physiological processes into play to counteract the adverse effect of heat stress and maintain thermal equilibrium (Castanheira et al., 2010).

Effect of heat stress on the physiological parameters in goats: Goats strive to maintain their body temperature within a narrow range to some extent, even under adverse climatic conditions. It is reported that if the rectal temperature is 39^{o}C or above (in a cow) during afternoon, it is possible to be heat stressed (Advendano-Reyes, 2012). Rectal temperature is the most common indicator of body temperature and considered as a reflection of core body temperature (Al-Tamimi, 2007) and physiological parameters related to homeothermy (Fig.1) and consequently adaptive depression of the metabolic rate associated with reduced appetite (Silanikove, 2000).

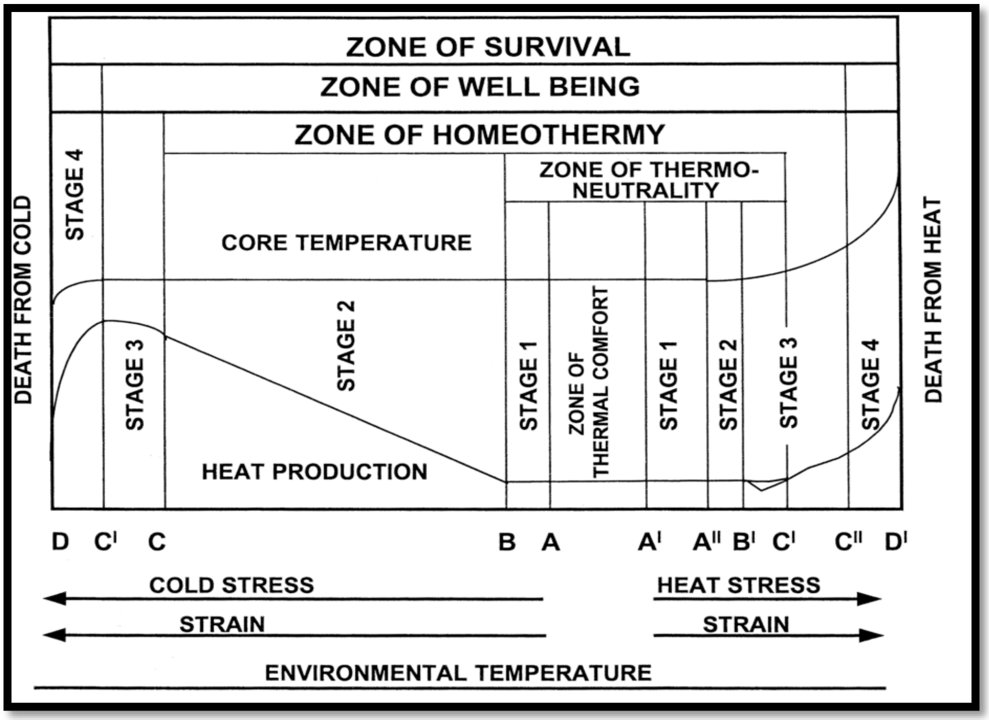

Fig. 1. Schematic presentation of the zones of survival, well being, and homeothermy in respect to environmental conditions in ruminants (Adopted from Silanikove, 2000).

The results of present study (Table 2) revealed that average CT, ST, RT and RR were higher in exposed animals than in control animals. These increases under hot summer conditions indicated that animals were subjected to heat stress (Al-Haidary et al., 2012; Minka and Ayo, 2012). It was also evident that there was a significant (P ≤ 0.05) increase in RR of exposed animals (55.6 and 60.4, respectively) than unexposed animals (45.6 and 47, respectively) in Baladi and Shami goats. Coat temperature and skin temperature also have the same trend. There was significant (P ≤ 0.05) increase of CT in exposed animals (39°C and 38.5°C, respectively) than unexposed animals (34.4°C and 35.4°C, respectively) in Baladi and Shami goats. Also, there was significant (P ≤ 0.05) increase in skin temperature in exposed animals (37.1°C and 36.6°C, respectively) than unexposed animals (36.9°C and 36.3°C, respectively) in Baladi and Shami goats.

Animals maintain the body temperature thermal equilibrium congener's dispersion of excess heat from their bodies when exposed to high temperatures. This is accompanied by many biological functions, and an increase in the rate of breathing or panting is the most obvious reaction. Under these circumstances, the animal body temperature expressed in increased body temperature when the body fails to maintain thermal equilibrium (Marai et al., 2007).

Additionally, significant increase of CT and ST during the summer season was one of physiological responses of animals exposed to heat stress (Al-Tamimi, 2007). This increase in ST during summer of exposed animals is related to vasodilatation of skin capillary bed and consequent increase in the blood flow to the skin surface to facilitate heat dissipation (McManus et al., 2009; Al-Samawi et al., 2014).

Table 2: Least square mean and SE of physiological parameters of Baladi and Shami goats as affected by solar radiation during summer season

Parameter/ Breed	Un-Exposed	Exposed	Overall
CT: Coat Temperature (°C)			
Baladi	34.40 ± 0.91	39.00 ± 0.91	36.70 ± 0.68
Shami	35.40 ± 0.91	38.50 ± 0.91	36.95 ± 0.68
Overall	34.90 ± 0.68 [b]	38.75 ± 0.68 [a]	---
ST: Skin Temperature (°C)			
Baladi	36.90 ± 0.50	37.10 ± 0.50	37.00 ± 0.35
Shami	36.30 ± 0.50	36.60 ± 0.50	36.45 ± 0.35
Overall	36.60 ± 0.35	36.85 ± 0.35	---
RT: Rectal Temperature (°C)			
Baladi	38.31 ± 0.21	38.81 ± 0.21	38.56± 0.15
Shami	38.80 ± 0.21	38.94 ± 0.21	38.87± 0.15
Overall	38.56 ± 0.15 [b]	38.88 ± 0.15 [a]	---
RR: Respiration rate (Breath/Min)			
Baladi	45.60 ± 3.32	55.60 ± 3.32	50.60 ± 2.35
Shami	47.00 ± 3.32	60.40 ± 3.32	53.70 ± 2.35
Overall	46.30 ± 2.35 [b]	58.00 ± 2.35 [a]	---

Means with different super scripts (a, b) in the same row for a particular parameter differed significantly ($P \leq 0.05$).

The most obvious effect of heat stress on the respiration rate and blood vessels function was the significant increase of heat dissipation in exposed Shami goats than Baladi goats. An increase in blood flow was required to maximize body's response to heat stress. This increase in blood flow was done by an increase in heart function and blood vessels as a compensatory mechanism to avoid shock (Cunningham, 1997).

The animals responded to heat stress by increase in heart rate which lead to increased blood flow from the heart to the surface to increase the chance of heat loss of sensible or active (loss by conduction, radiation and convention) and insensible or passive (heat was used to vaporize water) means (Marai et al., 2007).

Increase of respiratory frequency following heat stress had been previously reported in livestock, including goats (Minka and Ayo, 2012). Therefore, RR was used as an indicator of heat stress, and used to estimate the negative effects of the environmental temperature (Alamer and Al-Hozab, 2004). The increase of RR during summer season in the present study indicated heat stress and panting was one of the mechanisms in animals to dissipate excess heat through evaporation (Marai et al., 2007; Al-Haidary et al., 2012).

There was marked hyperthermia in goats exposed to HS and all the physiological parameters were elevated. However, the most intriguing results were the interactions between temperature and types of goats. The general homeostatic responses to thermal stress in mammals include elevated respiration rate, panting, drooling of saliva, reduced heart rates, profuse sweating, and reduced feed intake (Silanikove, 1992). Respiration rates of goats in this study were increased during heat stress in an effort to dissipate heat through the respiratory tract.

Effect of heat stress on hematological parameters in goats: The present results (Table 3) revealed that exposure to heat stress affected RBC's, MCHC, HGB and HCT ($P \leq 0.05$).

Table 3: Least square Mean and SE of the hematological parameters of Baladi and Shami goats as affected by solar radiation during summer season

Parameter/ Breed	Un-Exposed	Exposed	Overall
RBC's: erythrocytes cell counts ($10^3/m^3$)			
Baladi	1280 ± 42.61	1680 ± 42.61	1480 ± 30.13^x
Shami	1780 ± 42.61	2180 ± 42.61	1980 ± 30.13^y
Overall	1530 ± 30.13^b	1930 ± 30.13^a	---
WBC's: white blood cells ($10^3/m^3$)			
Baladi	6.77 ± 0.78	6.61 ± 0.78	6.69 ± 0.55
Shami	5.95 ± 0.78	5.64 ± 0.78	5.80 ± 0.55
Overall	6.36 ± 0.55^b	6.13 ± 0.55^a	---
ANL: absolute number of lymphocytes ($10^3/\mu l$)			
Baladi	5.61 ± 0.71	6.41 ± 0.71	6.01 ± 0.50
Shami	5.32 ± 0.71	5.08 ± 0.71	5.21 ± 0.50
Overall	5.47 ± 0.50	5.75 ± 0.50	---

ANM: absolute number of monocytes (10^3/µl)			
Baladi	**0.69 ± 0.24**	**0.89 ± 0.24**	**0.79 ± 0.17**
Shami	**0.60 ± 0.24**	**0.44 ± 0.24**	**0.52 ± 0.17**
Overall	**0.64 ± 0.17**	**0.66 ± 0.17**	**---**
ANG: absolute number of granulocytes (10^3/µl)			
Baladi	**0.70 ± 0.21**	**0.35 ± 0.21**	**0.52 ± 0.15**
Shami	**0.30 ± 0.21**	**0.17 ± 0.21**	**0.24 ± 0.15**
Overall	**0.50 ± 0.15**	**0.26 ± 0.15**	**---**
RNL: relative number of lymphocytes (10^3/µl)			
Baladi	**81.68 ± 3.78**	**88.25 ± 3.78**	**84.96 ± 2.68**
Shami	**87.03 ± 3.78**	**88.51 ± 3.78**	**87.77 ± 2.68**
Overall	**84.35 ± 2.68**	**88.38 ± 2.68**	**---**
RNM: relative number of monocytes (10^3/µl)			
Baladi	**8.55 ± 1.28**	**8.84 ± 1.28**	**8.70 ± 1.81**
Shami	**11.35 ± 1.28**	**8.71 ± 1.28**	**10.03 ± 1.81**
Overall	**9.95 ± 1.81**	**8.78 ± 1.81**	**---**
RNG: relative number of granulocytes (10^3/µl)			
Baladi	**2.77 ± 0.69**	**2.91 ± 0.69**	**2.84 ± 0.49^x**
Shami	**3.59 ± 0.69**	**3.16 ± 0.69**	**3.37 ± 0.49^y**
Overall	**3.18 ± 0.49**	**3.03 ± 0.49**	**---**

HGB: Hemoglobin (g/dl)			
Baladi	**8.47 ± 0.22**	**7.66 ± 0.22**	**8.07 ± 0.15^{x}**
Shami	**7.54 ± 0.22**	**6.69 ± 0.22**	**7.12 ± 0.15^{y}**
Overall	**8.01 ± 0.15^{a}**	**7.18 ± 0.15^{b}**	**---**
HCT: Hematocrit (%)			
Baladi	**35.58 ± 0.32**	**34.64 ± 0.32**	**35.11 ± 0.23^{x}**
Shami	**34.60 ± 0.32**	**33.97 ± 0.32**	**34.29 ± 0.23^{y}**
Overall	**35.09± 0.23^{a}**	**34.31 ± 0.23^{b}**	**---**
MCV: mean corpuscular volume (IL)			
Baladi	**55.10 ± 1.36**	**58.63 ± 1.36**	**56.86 ± 0.96**
Shami	**58.52 ± 1.36**	**60.47 ± 1.36**	**59.50 ± 0.96**
Overall	**56.81 ± 0.96**	**59.55 ± 0.96**	**---**
MCH: mean corpuscular hemoglobin (Pg)			
Baladi	**13.12 ± 0.44**	**12.87 ± 0.44**	**13.00 ± 0.31**
Shami	**12.79 ± 0.44**	**11.96 ± 0.44**	**12.38 ± 0.31**
Overall	**12.96 ± 0.31**	**12.41± 0.31**	**---**
MCHC: mean corpuscular hemoglobin concentration (g/dl)			
Baladi	**23.80 ± 0.57**	**22.07 ± 0.57**	**22.93 ± 0.40^{x}**
Shami	**21.80 ± 0.57**	**19.71 ± 0.57**	**20.76 ± 0.40^{y}**
Overall	**22.80 ± 0.40^{b}**	**20.89 ± 0.40^{a}**	**---**

Means with different super scripts in the same row (a, b) and in the same column (x, y) for a particular parameter differed significantly ($P \leq 0.05$).

The lowest RBC's concentration was recorded in exposed Shami goats. Furthermore, HGB, HCT and MCHC showed significant ($P \leq 0.05$) differences between exposed and unexposed and between Baladi and Shami goats ($P \leq 0.05$).

Thermal stress is known to alter the homeostatic mechanism of animals resulting in impaired erythropoiesis. High environmental temperature increases the oxygen consumption of animals by increasing the respiration rate. The higher oxygen intake increases the partial pressure of oxygen in the blood, decreases erythropoiesis that in turn reduces the number of circulating erythrocytes and thus reducing PCV and Hb values (Temizel et al., 2009; Sivakumar et al., 2010; Kumar et al., 2011).

Significant (P ≤ 0.05) decrease in hemoglobin and PCV levels during thermal stress could increase the attack of free radicals on the erythrocyte membrane, which is rich in lipid content, and ultimate cause lysis of RBC's or inadequate nutrient availability for hemoglobin synthesis as the animal consumes less feed or reduces voluntary intake under heat stress. During summer stress, a significant depression in PCV may also be due to hemodilution effect where more water is transported into the circulatory system for evaporative cooling (EL-Nouty et al., 1990).

The present results (Table 3) revealed that ANL, ANM, RNL increased, while ANG, RNM and RNG decreased insignificantly (P ≥ 0.05) due to exposure to heat stress in treated groups. It has been reported that heat stress decreases packed cell volume and hemoglobin (Sivakumar et al., 2010), and white blood cells (Okoruwa, 2014) in goats. Another explanation for increase in packed cell volume and hemoglobin levels could be either increased effect of free radicals on the red blood cells membrane, which is rich in lipid content, and ultimate cause of lysis of red blood cell (Leonart et al., 1989) or availability of adequate nutrients for synthesis of hemoglobin as the animal consumes more feed or decreases voluntary intake under heat stress (Gupta et al., 2013).

Effect of heat stress on biochemical parameters in goats: The plasma levels of ALT increased significantly (P ≤ 0.05) in exposed than in unexposed animals in both breeds while AST increased insignificantly (P ≥ 0.05) in exposed than in unexposed animals in both breeds (Table 4). Alanine and aspartate transaminases are helpful indicators with regard to the welfare of animals. Serum ALT value found to increase during heat stress in goats (Sharma and Nalini, 2011). Non-significant (P ≥ 0.05) changes were observed in AST level in goats during heat stress (Ocak et al., 2009; Sharma and Nalini, 2011).

Antioxidants (ALP and Creatinine) increased insignificantly (P ≥ 0.05) in exposed than in unexposed goats. Increased enzymatic levels reflect higher metabolic activities during stress. It has been reported that heat stress reduces alkaline phosphatase and lactate dehydrogenase activities in sheep (Sevi et al., 2001).

The concentrations of total proteins, albumin and globulin decreased insignificantly (P ≥ 0.05) in exposed than in unexposed goats. This may be due to the increase in plasma volume because of heat shock, which decreases plasma protein concentration (Dangi et al., 2012). Total proteins, albumin and globulin levels decrease in goats subjected to HS (Helal et al., 2010). In contrast, HS increases total proteins and albumin in goats (Okoruwa, 2014) which could be due to dehydration which has been reported to occur as a result of increased respiration rate.

The plasma means of glucose concentration decreased insignificantly (P ≥ 0.05) in exposed goats than in unexposed ones in both breeds. However, heat exposure influenced significantly (P ≤ 0.05) total lipids and cholesterol in goats. Blood glucose and total cholesterol levels are physiological adaptation mechanisms that can be affected by high ambient temperatures, where greater differences could be observed in their values under hot conditions than in the comfort zone. Some researchers have reported that hot climatic conditions decrease blood glucose and total cholesterol levels (Marai et al., 1995; Ocak et al., 2009), while some reports contradicted (Webster, 1976).

Bahga et al. (2009) have reported that blood glucose and total cholesterol level decrease during the summer season and increase during winter season in goats. Determination of biochemical parameters may be important in establishing the effect of heat stress. The marked decrease in total cholesterol levels may have a relation with the increase in total body water or the decrease in acetate concentration, which is the primary precursor for the synthesis of cholesterol.

Table 4: Least square Mean and SE of biochemical parameters of Baladi and Shami goats as affected by solar radiation during summer season

Parameter/ Breed	Un-Exposed	Exposed	Overall
Alanine transaminase (IU/l)			
Baladi	18.43 ± 0.15	20.07± 0.15	19.25 ± 0.11
Shami	18.40 ± 0.15	20.20 ± 0.15	19.30 ± 0.11
Overall	18.41 ± 0.11 [b]	20.13 ± 0.11 [a]	---
Aspartate transaminase (IU/l)			
Baladi	23.67± 1.03	24.21 ± 1.03	23.94± 0.3
Shami	23.25 ± 1.03	25.88 ± 1.03	24.57 ± 0.73
Overall	23.46 ± 0.73	25.04 ± 0.73	---
Urea (mg/dl)			
Baladi	110.43 ± 16.82	131.27± 16.82	120.85± 11.89 [x]
Shami	143.70 ± 16.82	183.43± 16.82	163.57± 11.89 [y]
Overall	127.07 ± 11.89	157.35 ± 11.89	---
Creatinine (mmol/L)			
Baladi	44.48 ± 1.02	46.03± 1.02	45.25 ± 0.72
Shami	44.45 ± 1.02	46.56 ± 1.02	45.51 ± 0.72
Overall	44.47 ± 0.72	46.29 ± 0.72	---
Alkaline phosphatase (IU/L			
Baladi	16.58 ± 4.73	15.21 ± 4.73	15.89 ± 1.44 [x]
Shami	23.96 ± 4.73	22.83 ± 4.73	23.40 ± 1.44 [y]
Overall	20.27 ± 1.44	19.02 ± 1.44	---

Glucose (mmol/L)			
Baladi	21.40 ± 0.73	14.77 ± 0.73	18.08 ± 0.52 ^{x}
Shami	13.83 ± 0.73	12.63 ± 0.73	13.23 ± 0.52 ^{y}
Overall	17.62 ± 0.52 ^{a}	13.70 ± 0.52 ^{b}	---
Total lipids (mmol/L)			
Baladi	2641.67 ± 136.47	1783.33 ± 136.47	2212.50 ± 96.50
Shami	2566.67 ± 136.47	2000.00 ± 136.47	2283.33 ± 96.50
Overall	2604.17 ± 96.50 ^{a}	1891.67 ± 96.50 ^{b}	---
Cholesterol (mg/dl)			
Baladi	63.03 ± 1.54	64.10 ± 1.54	63.57 ± 1.09
Shami	75.07 ± 1.54	54.80 ± 1.54	64.93 ± 1.09
Overall	69.05 ± 1.09 ^{a}	59.45 ± 1.09 ^{b}	---
Total Protein (mmol/L)			
Baladi	8.63 ± 0.54	9.53 ± 0.54	9.08 ± 0.38 ^{x}
Shami	12.00 ± 0.54	10.17 ± 0.54	11.08 ± 0.38 ^{y}
Overall	10.32 ± 0.38	9.85 ± 0.38	---
Albumin (mmol/L)			
Baladi	3.40 ± 0.41	3.47 ± 0.41	3.43 ± 0.29 ^{x}
Shami	3.90 ± 0.41	5.13 ± 0.41	4.52 ± 0.29 ^{y}
Overall	3.65 ± 0.29	4.30 ± 0.29	---
Albumin/Globulin ratio			
Baladi	0.68 ± 0.15	0.58 ± 0.15	0.63 ± 0.10
Shami	0.40 ± 0.15	1.18 ± 0.15	0.79 ± 0.10
Overall	0.54 ± 0.10 ^{b}	0.88 ± 0.10 ^{a}	---
Globulin (mmol/L)			
Baladi	5.23 ± 0.59	6.07 ± 0.59	5.65 ± 0.42
Shami	8.10 ± 0.59	5.03 ± 0.59	6.56 ± 0.42
Overall	6.67 ± 0.42	5.55 ± 0.42	---

Means with different super scripts in the same row (a, b) and in the same column (x, y) for a particular parameter differed significantly ($P \leq 0.05$).

The decrease in blood glucose could be related to decrease in the availability of nutrients and lower production rate of propionate (Mohamad, 2012) or due to increase in plasma glucose utilization to provide energy for muscular expenditure required for high muscular activity associated with increased respiration rate (Sejian et al., 2012).

Effect of heat stress on blood electrolytes in goats: The plasma concentration (Table 5) of sodium (Na^+) decreased ($P \leq 0.05$) in exposed goats than unexposed groups (111.18 and 126.83, mEq/L) respectively. It was higher ($P \leq 0.05$) in Shami than in Baladi goats. On the other hand, K^+ and Cl^- increased ($P \leq 0.05$) in exposed than in unexposed goats. These values were higher ($P \leq 0.05$) in Baladi than in Shami goats.

Table 5: Least square Mean and SE of electrolytic parameters of Baladi and Shami goats as affected by solar radiation during summer season

Parameter/ Breed	Un-Exposed	Exposed	Overall
Sodium (mEq/L)			
Baladi	121.10 ± 3.40	108.37 ± 3.40	114.73 ± 2.41^{x}
Shami	132.57± 3.40	114.00 ± 3.40	123.28 ± 2.41^{y}
Overall	126.83 ± 2.41^{a}	111.18 ± 2.41^{b}	---
Potassium (mEq/L)			
Baladi	0.16 ± 0.04	0.63 ± 0.04	0.40 ± 0.04^{x}
Shami	0.10 ± 0.04	0.33 ± 0.04	0.22 ± 0.04^{y}
Overall	0.13 ± 0.04^{b}	0.48 ± 0.04^{a}	---
Phosphorus (mEq/L)			
Baladi	18.53 ± 0.78	15.63 ± 0.78	17.08 ± 0.55
Shami	15.43 ± 0.78	18.83 ± 0.78	17.13 ± 0.55
Overall	16.98 ± 0.55	17.23 ± 0.55	---
Chloride (mEq/L)			
Baladi	99.07± 1.37	106.13 ± 1.37	102.60 ± 0.97^{x}
Shami	99.70 ± 1.37	95.03 ± 1.37	97.37 ± 0.97^{y}
Overall	99.38 ± 0.97^{b}	100.58 ± 0.97^{a}	---

Means with different super scripts in the same row (a, b) and in the same column (x, y) for a particular parameter differed significantly ($P \leq 0.05$).

Heat stress challenges the animal's ability to maintain its mineral balance (Sivakumar et al., 2010). The serum concentrations of sodium, potassium and chloride decreased in goats subjected to heat stress due to the fact that HS animals lost more potassium and chloride in sweat than non-HS animals, and the blood volume is expanded because water is transported into the circulatory system for evaporative cooling (Al-Haidary, 2004).

Heat stressed animals lose more potassium and chloride in sweat than non-heat stressed animals (Singh et al., 2012). Loss of electrolytes during heat stress has been reported by earlier workers (Shalit et al., 1991; Kumar et al., 2010). This decrease occurs mainly due to increased excretion of electrolytes in urine, sweat and other secretions to alleviate heat stress.

Effect of heat stress on immunological parameters in goats: Our results (Table 6) showed that plasma concentration of cytokines (IL-1 and IL-6) increased significantly ($P \leq 0.05$) in exposed goats than in unexposed goats. However, IL-1 was higher ($P \leq 0.05$) in Baladi goats than in Shami goats, while IL-6 was higher ($P \leq 0.05$) in Shami goats than in Baladi goats.

During prolonged exposure to solar radiation (heat stress), the level of inflammatory cytokines increases, since heat exposure stimulates the release of IL-1 and IL-6, which can raise the thermoregulatory mechanism resulting in increased heat storage.

The short-term transient increase in heat shock proteins after exposure is mediated by the cytokine system and mainly by IL-6. That is useful in several beneficial adaptive effects of heat stress on exhaustive exposure-induced changes in cytokines and TAC and inflammation parameters that heat could successfully be achieved within a short period of time. This results in inhibitory effect of free radicals and reduces the negative effects resulting from them, especially on the cell membrane.

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In general, these enzymatic antioxidants act by scavenging both intracellular and extracellular superoxide radicals and preventing lipid peroxidation of the plasma membrane. Heat stress stimulates excessive production of free radicals such as reactive oxygen species (superoxide anion radicals, hydroxyl radical, hydrogen peroxide and singlet oxygen) which are continuously produced in the course of normal aerobic metabolism, and they can damage healthy cells if not eliminated.

Chronic exposure to thermal stress can cause disease, reduce growth, decrease productive and reproductive performance and, in extreme cases, lead to death. (Sarangi, 2018). The oxidative stress increases in desert goats during summer as superoxide dismutase increases (Kumar et al., 2011).

Long-term heat acclimation in their impact on the physiological state of goats analyzed, revealed the influence of short and long-term exposure to a hot environment and found that body temperatures from chronically heat-stressed small ruminants (several days) gradually return to no heat stress values. This shows it is important to determine the serum proteome changes after long-term heat stress.

Table 6: Least square Mean and SE of the Interleukins and enzymes of Baladi and Shami goats as affected by solar radiation during summer season

Parameter/ Breed	Un-Exposed	Exposed	Overall
Interlukin 1β (Pg/ml)			
Baladi	97.92± 0.62	113.62 ± 0.62	105.77 ± 0.44[x]
Shami	73.71 ± 0.62	116.76± 0.62	95.24 ± 0.44[y]
Overall	85.81 ± 0.44 [b]	115.19 ± 0.44 [a]	---
Interlukin-6 (Pg/ml)			
Baladi	93.06± 0.59	103.06± 0.59	98.06 ± 0.71[x]
Shami	95.26± 0.59	110.26± 0.59	102.76 ± 0.71[y]
Overall	94.16 ± 0.71 [b]	106.66 ± 0.71 [a]	---
Total antioxidant capacity (mU/L)			
Baladi	0.15± 0.04	0.20± 0.04	0.17 ± 0.02
Shami	0.19 ± 0.04	0.21± 0.04	0.20 ± 0.02
Overall	0.17 ± 0.02	0.20 ± 0.02	---
Glutathione reductase (mU/ml)			
Baladi	92.03 ± 15.60	114.23 ± 15.60	103.13 ± 11.03
Shami	81.16 ± 15.60	101.73 ± 15.60	91.45 ± 11.03
Overall	86.60 ± 11.03	107.98 ± 11.03	---

Means with different super scripts in the same row (a, b) and in the same column (x, y) for a particular parameter differed significantly ($P \leq 0.05$).

Total antioxidant activity (TA) is considered as a cumulative action of all antioxidants present in serum and body fluids. This variable provides relevant information that will effectively describe the dynamic equilibrium between pro-oxidant and anti-oxidant agents in the plasma (Ghiselli et al., 2000). Indeed, TA is viewed as a helpful tool to measure stress in ruminants (Pregel et al., 2005).

CONCLUSION

In conclusion, goats exposed to heat stress during the summer season were well adapted through some physiological and biochemical changes. Additionally, several beneficial adaptive effects of heat stress on exhaustive exposure-induced changes in cytokines and in changing antioxidant levels and inflammation parameters due to heat could have been successfully achieved within a short period of time. The preliminary findings of this study have significant implications in monitoring the adaptation to heat stress especially in native breeds of animals, which is important for the goat breeder (poor man' cow in desert), who has to be physically active (seeking bountiful pastures) in thermally stressful environmental conditions (e.g., Bedouin and Small livestock holders).

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UNDERTAKING

It is certified that the research paper '**IMPACT OF HEAT STRESS ON PHYSIOLOGICAL, HEMATOLOGICAL, BIOCHEMICAL, ELECTROLYTIC, IMMUNOLOGIC AND ANTIOXIDANT PARAMETERS IN BALADI AND SHAMI GOATS OF EGYPT'** is an original research work carried out by the author in the Department of Animal and Poultry Breeding, Desert Research Center, Cairo, Egypt. It has neither been published nor contemplated for publication elsewhere.

Dr Fawzy E. Younis

CORRESPONDING AUTOR