

Comparative Study of Some Phenotypic and Coat Parameters in Relation to Adaptability Performance of Balady and Damascus Goats

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Abstract: This study was performed during summer season using 10 adult Bucks of Balady and Damascus goats (5 each). The study was carried out at Abou-El-feta, Northern Sinai, Egypt. Animals were allowed to adapt in the sheltered pens conditions (7 days) as adaptation period followed by a control period (period I) for 2 days inside the separated enclosures (shaded), this was followed by (period II) for short- (2 days) and long-term (4 days) of exposure to solar radiation (from sunrise till sunset), then followed by 2 days (period III) for recovery. The thermo-physiological parameters were measured four times/day at 06:00 (morning), 12:00 (mid-day), 18:00 (evening) and 24:00 hr (mid-night) throughout the experimental periods. In both breeds, regardless the duration of exposure to solar radiation, thermoregulatory measurements (rectal, skin and coat temperature as well as respiration rate) increased ($P<0.01$) significantly in parallel to the increase in temperature-humidity index (THI), while heart rate (HR) tended to followed the opposite trend with THI at mid-days measure. Significant increase ($P<0.01$) happened in thermoregulatory measurements when the time exposure to solar radiation increased. Data in this study illustrated that both breeds had the potentiality to be adapted to hot environment. presence of inner coat (2.4 vs. 1.7), coat depth (2.1 vs. 1.5), long hair (13.1 vs. 9.75), ear area (293.0 vs. 180.8) and hair color (light and dark) in Damascus and Balady goats, respectively help Damascus goats to be adapted to hot environment. Further study needs to investigate the role of hair scales in sun rays reflection.

Key words: Goats • Heat stress • Coat characteristics • Fiber Scales • Breeds • Thermo-physiological responses • Linear body measurements

INTRODUCTION

Goats are considered one of the farm animals although they are widely accepted as a desert animal. In Egypt, goats are raised mainly in desert areas i.e. the North West Coastal zone and in the Sinai Peninsula. Goats are much different from sheep in their behavior and are more adapted to harsh conditions. They can survive and produce where no other domestic animal (except camels) can survive [1]. Environmental factors (ambient temperature, relative humidity, solar radiation and wind speed), animal factors (breed, coat color, health status) and thermoregulatory mechanism (circulatory adjustments, sweating and panting) have a significant impact on the energy exchange between the animal and the environment [2]. The type and color of coat found is very important for heat resistance [3, 4]. It is thought that animals with a dark coat and therefore with greater absorption of thermal radiation, are more susceptible to heat stress than those with a light colored coat [5].

Balady goats are the primary breed in tropical and subtropical regions, they are well known for their superior adaptability to harsh environmental stresses (heat, drought, scarcity of rangeland) compared with other farm animals. On the other hand, Damascus (Shami) goats are considered an important source of high milk and meat production for the Bedouin people. They adapted to the Eastern Mediterranean region. Damascus goats are introduced into Sinai Peninsula because of their high production of milk and meat. However, there have been insufficient studies about adaptation capability of Damascus (Shami) breed compared with Balady goats under Sinai climatic conditions. Morphological differentiation are found between Balady and Damascus breeds such as animal dimensions, ear size, neck length, coat and skin color, hair characteristics and live body weight. Therefore, it is expected that performance of Damascus goat could be different in the thermoregulatory ability compared to Balady goat under heat stress. Therefore, this study aimed to evaluate the physiological

adaptability of the local breed (Balady) compared to exotic (Damascus) breed under short- and long-term exposure to solar radiation.

MATERIALS AND METHODS

Site of Study: Geographically, the Experimental Unit of the Small Ruminant Research at Abou-El-feta village which lies between latitudes $31^{\circ} 7' 54.84''$ N and longitudes $33^{\circ} 48' 11.52''$ E. It lies at 450 Km East-west of the Mediterranean shoreline and at 25 Km of Al-arish city, Northern Sinai, Egypt.

Meteorological Conditions: During summer season, climatic components like ambient temperature (AT, $^{\circ}\text{C}$), relative humidity (RH, %) were recorded using digital Thermo-hygrometer, ambient heat radiant (AHR, $^{\circ}\text{C}$) was measured by a mercury thermometer with its bulb centrally placed in a thin copper sphere that is 20cm in diameter and painted flat black. This instrument was placed at about 1.5 meters above the ground. A temperature-humidity index (THI) was calculated according to Thom [6] using the following equation:

$$\text{THI} = 0.8 \times \text{AT}, ^{\circ}\text{C} + (\text{RH}, \%) \times (\text{AT}, ^{\circ}\text{C} - 14.4) / 100 + 46.4$$

All climatic measurements were recorded four times daily at 06:00 (morning), 12:00 (mid-day), 18:00 (evening) and at 24:00 hr (mid-night).

Live Body Weight (LBW): Live body weight (LBW, kg) was measured at the beginning and end of each experimental period. The rate of change in LBW was calculated.



Photo 1: Balady breed

Animals and Experimental Design: A total of 10 Bucks of two breeds of goat (5 of the short-eared Balady breed, characterized by its medium size, mainly black color and short hair and 5 of the long-eared Damascus breed, characterized by its big size, light brown color and long hair) were used. The animals were at 18 months of age, the initial body weights were 29.86 ± 2.41 and 49.22 ± 1.74 kg for Balady and Damascus breeds, respectively, Photos (1 and 2). The animals were allowed to adapt in the sheltered pens conditions (7 days) as adaptation period (no measurements were taken during this period). The total duration of experiment was 8 days, which was divided into three consecutive periods, 2 days for the pre-exposure to solar radiation (Period I), followed by 4 days for short-term and long-term exposure to solar radiation (Period II) and later 2 days for recovery period (Period III). The same animals of each breed were used repeatedly in all experimental periods.

The animals were fed Alfalfa hay twice daily (11:00 and 18:00 h) based on live body weight (LBW) to meet the metabolic energy maintenance requirement according to Kearn [7]. On average hay samples contained, 87.5% dry matter (DM), 12.9% ash, 14.2% crude protein (CP), 30.2% crude fiber (CF) and 3.2% ether extract (EE) on a dry matter bases according to AOAC [8]. Fresh water was given once daily *ad lib*. Throughout the experimental periods, animals proved to be free from internal and external parasites. All animals were kept under close clinical observation, according to Kelly [9].

Thermo-physiological Measurements: Rectal (RT, $^{\circ}\text{C}$), skin, (ST, $^{\circ}\text{C}$), coat (CT, $^{\circ}\text{C}$) temperatures, respiration (RR, rpm) and heart (HR, bpm) rates were measured 4 times/day at 06:00 (morning), 12:00 (mid-day), 18:00



Photo 2: Damascus breed

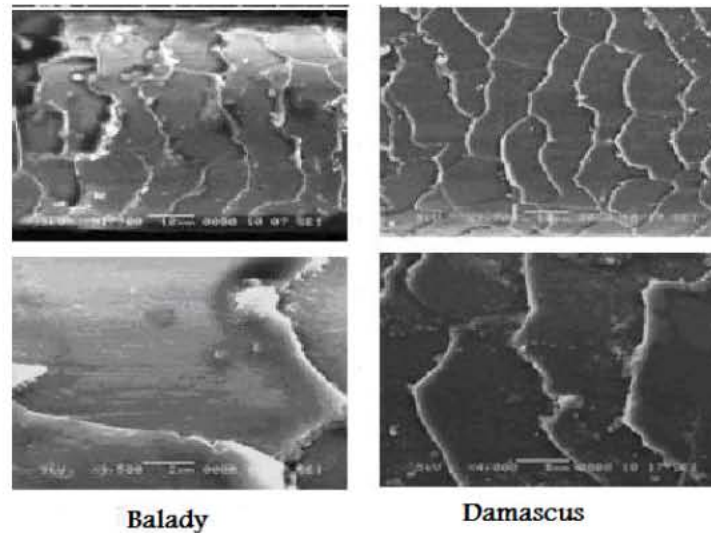


Image 1: Scales of both Damascus and Balady hair taken by (SEM)

(Evening) and 24:00 hr (mid-night) throughout the experimental periods. At each time, RT, ST and CT parameters were measured using thermistor probes (Model 46 TUC Tele-thermometer, YSI, Yellow Springs, Ohio, U.S.A). Heart rate was measured with Polar monitor (S610, Polar, Lake Success, NY) along the experimental periods (beats per minute). RR was measured by counting the flank movements (respirations per minute).

Morphological Measurements: All the linear body measurements were taken in the morning before the animals were fed and not-strained (calmed). The following body linear measurements were taken on each of the animals examined as described by Brown *et al.* [10] and adopted by Ortheruata and Olutogun [11]. Each dimension taken was recorded in centimeter as follows: Body length (BL): body length was measured using a tap-rule, as the distance from the occipital protuberance to the base of the tail. Body height at front (BHF): A flat platform was used upon which the animal was placed. The height at wither was measured as the distance from the surface of the platform to the withers using a measuring tape. Heart girth (HG): The heart girth was measured by taking the measurement of the circumference of the chest with a tape rule. Ear length (EL): Distance between the tip of the ear and the point of attachment to the head. Ear width (EW): The distance between the two sides of the ear at the middle. Ear area (EA) measured when putting the animal ear on a paper and then drawing the area and measuring the area using *Adobe Photoshop* program after scanning the shape.

Hair Measurements: Coat depth measured using a ruler and recorded as the vertical distance between the skin surface and the coat surface. Inner coat were measured on the animal positions according to the grading system: grade (1) had no fine fiber, grade (2) had few amount of fine fibers, grade (3) had remarkable amount of fine fibers, grade (4) had a good amount of fine fibers and grade (5) had plenty amount of fine fibers. Hair samples were taken from six body positions, three dorsal (withers, Wth, back, Bk and rump, Rp) and three laterals (shoulder, Sh, mid-side, Ms and Britch, Br). Fiber diameter (FD) was measured from ten samples using image analyzer (LEICA Q 500 MC) with lens 4/0.12. A section of 0.2 mm in length was cut by a Hand-Microtome at a level of 2cm from the base of the staples of each sample. These cuttings were put on a microscope slide with 2-3 drops of paraffin oil and covered with a slide cover. About five hundred fibers were taken at random and measured from each sample. Medullated fibers percentage (M%) was recorded as the percentage of number of medullated fibers from the corresponding total fibers present in each sample during measuring FD. Fiber length measured in 50 fibers of each sample from back position using a ruler, much attention was taken not to stretch the fiber. Fiber scales characteristics measured using scan electron microscope.

Statistical Analysis: Data were analyzed with the general linear model (GLM) of SAS [12]. Sources of variation for all dependent variables were tested. All effects were assumed fixed (Breed, period and time). Animals within breeds considered as repeated measurements to avoid the

individual differences among animals. Comparisons among means within each classification were tested using Duncan's New Multiple Range Test [13].

RESULTS AND DISCUSSION

Climatic Conditions: Ambient temperature (AT, °C), relative humidity (RH, %) and temperature-humidity index (THI) throughout the experimental periods are shown in Figure 1. Temperature humidity index (THI) is commonly used as an indicator of the degree of climatic stress on animals where a THI of 72 and below is considered as no heat stress (cool), 73-77 as mild heat stress (HS), 78-89 as moderate and above 90 as severe [14]. In the present study, we observed that THI was the minimum at 6:00

(morning) and 12:00 hr (mid-night) during pre- and post-heat stress (74.8 and 69.3 vs. 77.9 and 73.2), while it recorded the highest values at 12:00 hr (mid-day) during pre- and post-heat stress (79.10 vs. 87.40).

Body Measurements in Both Balady and Damascus

Breeds: Photos (1 and 2) as well as results in Table 1 clarify that Damascus goats had significantly ($P<0.01$) higher values in all body measurements. The variability between the breeds reached 19.4 kg in live body weight (LBW), 13 cm in body length (BL), 10.2 cm in body height front (BHF), 6.8 cm in heart girth (HG), 8 cm in neck length (NL), 8.8cm in ear length (EL), 3 cm in ear width (EW) and 112.2 cm² in ear area (EA). The above result shows that expected surface area of Damascus goats will be higher

Table 1: The least square means and standard errors (\pm SE) for live body weight and body linear measurements of Balady and Damascus breeds

Item	Balady	Damascus	\pm SE
Coat color	Black	Light Brown	----
Live body weight (LBW), kg	29.8 ^a	49.2 ^b	1.230
Body length (BL), cm	63.6 ^a	76.6 ^b	2.272
Body height front (BHF), cm	68.4 ^a	78.6 ^b	2.100
Heart girth (HG), cm	77.6 ^a	84.4 ^b	3.370
Neck length (NL), cm	21.6 ^a	29.6 ^b	1.47
Ear length (EL), cm	19.0 ^a	27.8 ^b	1.034
Ear width (EW), Cm	8.0 ^a	11.0 ^b	0.500
Ear area (EA), cm ²	180.8 ^a	293.0 ^b	28.096

In each column means followed by different letters are significantly different

Table 2: Effect of short- and long-term exposure to solar radiation on mean diurnal rectal (RT, °C), skin (ST, °C) and coat (CT, °C) temperatures of Balady and Damascus goats during summer season at northern Sinai

Periods	Time	Balady			Damascus		
		RT, °C	ST, °C	CT, °C	RT, °C	ST, °C	CT, °C
Pre-exposure	MO	38.5 ^c \pm 0.21	33.0 ^a \pm 0.18	33.8 ^a \pm 0.37	38.6 ^a \pm 0.05	35.1 ^b \pm 0.18	33.2 ^a \pm 0.58
	MD	39.2 ^a \pm 0.06	36.0 ^a \pm 0.30	35.7 ^a \pm 0.34	39.4 ^b \pm 0.04	36.2 ^a \pm 0.31	34.5 ^a \pm 0.46
	EV	39.0 ^{ab} \pm 0.06	35.4 ^{ab} \pm 0.30	33.0 ^b \pm 0.60	39.2 ^a \pm 0.04	35.1 ^b \pm 0.28	33.1 ^a \pm 0.19
	MN	38.6 ^c \pm 0.21	34.9 ^a \pm 0.25	32.3 ^a \pm 0.17	39.0 ^a \pm 0.05	34.6 ^a \pm 0.19	33.3 ^a \pm 0.33
Overall mean		38.9 ^b \pm 0.07	34.8 ^a \pm 0.20	33.7 ^a \pm 0.24	39.0 ^b \pm 0.05	35.2 ^a \pm 0.13	33.5 ^a \pm 0.16
Period II	MO	38.8 ^a \pm 0.14	35.0 ^b \pm 0.40	36.2 ^b \pm 0.12	39.1 ^a \pm 0.17	34.2 ^a \pm 0.31	35.5 ^b \pm 0.28
Short-term	MD	39.9 ^a \pm 0.05	38.8 ^a \pm 0.14	40.2 ^a \pm 0.50	40.1 ^a \pm 0.10	37.1 ^a \pm 0.12	38.7 ^a \pm 0.50
Heat stress	EV	39.4 ^b \pm 0.22	36.1 ^b \pm 0.62	38.2 ^a \pm 0.39	39.6 ^a \pm 0.05	35.1 ^b \pm 0.32	36.4 ^b \pm 0.22
	MN	39.1 ^{bc} \pm 0.04	34.4 ^a \pm 0.52	35.4 ^b \pm 0.33	39.4 ^b \pm 0.09	34.3 ^{bc} \pm 0.25	33.6 ^a \pm 0.42
Overall mean		39.3 ^a \pm 0.08	36.1 ^{ab} \pm 0.31	38.2 ^a \pm 0.42	39.5 ^a \pm 0.07	35.2 ^a \pm 0.21	36.0 ^a \pm 0.32
Period II	MO	39.2 ^a \pm 0.04	37.0 ^b \pm 0.38	35.6 ^b \pm 0.19	39.2 ^a \pm 0.09	38.0 ^a \pm 0.32	34.4 ^b \pm 0.51
Long-term	MD	40.0 ^a \pm 0.03	37.8 ^a \pm 0.20	38.6 ^a \pm 0.24	40.3 ^a \pm 0.07	38.4 ^a \pm 0.17	37.2 ^a \pm 0.37
Heat stress	EV	39.6 ^a \pm 0.14	36.7 ^b \pm 0.15	37.2 ^b \pm 0.92	39.8 ^a \pm 0.06	37.8 ^a \pm 0.20	34.6 ^a \pm 0.24
	MN	39.4 ^{bc} \pm 0.05	36.0 ^a \pm 0.18	35.6 ^b \pm 0.44	39.5 ^a \pm 0.18	37.0 ^b \pm 0.36	34.3 ^b \pm 0.31
Overall mean		39.6 ^a \pm 0.05	36.9 ^a \pm 0.13	36.8 ^a \pm 0.27	39.7 ^a \pm 0.07	37.8 ^a \pm 0.12	35.1 ^b \pm 0.23
Period III	MO	38.8 ^a \pm 0.26	35.4 ^a \pm 0.33	34.6 ^a \pm 0.24	39.3 ^a \pm 0.25	35.8 ^a \pm 0.20	33.9 ^a \pm 0.08
Recovery period	MD	38.7 ^a \pm 0.09	36.2 ^a \pm 0.27	37.8 ^a \pm 0.32	39.5 ^a \pm 0.08	37.7 ^a \pm 0.40	34.5 ^{ab} \pm 0.44
(Shaded)	EV	39.0 ^a \pm 0.17	36.3 ^a \pm 0.15	37.2 ^a \pm 0.80	39.3 ^a \pm 0.12	36.2 ^b \pm 0.24	35.2 ^a \pm 0.58
	MN	38.8 ^a \pm 0.27	35.6 ^a \pm 0.41	35.2 ^a \pm 0.58	39.2 ^a \pm 0.18	36.8 ^{ab} \pm 0.37	33.6 ^a \pm 0.22
Overall mean		38.8 ^b \pm 0.07	35.9 ^a \pm 0.12	36.2 ^a \pm 0.29	39.3 ^a \pm 0.06	36.6 ^b \pm 0.15	34.3 ^{bc} \pm 0.16
Percent of compensatory		103.4	84.7	56.5	56.25	53.7	31.15

MO = morning, MD = mid-day, EV = evening, MN = mid-night

In each column means followed by different letters are significantly different, columns of overall mean in each period followed by different bold letters are significantly different

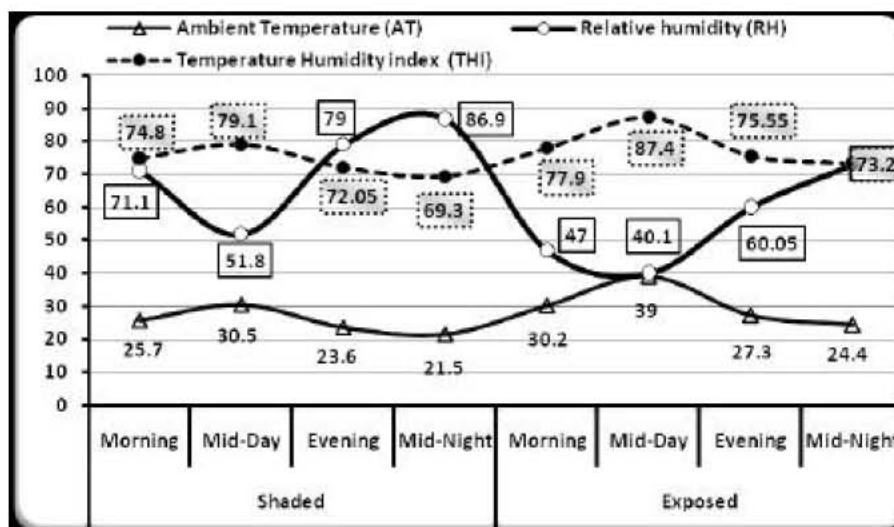


Fig. 1: Meteorological data during the experimental periods.

compared with Balady one. Moreover, morphological characteristics of animals are important in hot or cold climate. Johnson, [15] reported that, when the environmental temperature increases to 36°C, the ears and legs of sheep dissipate a high proportion of heat as these areas contribute about 23% of the body surface area.

At the start of study (pre-exposure to solar radiation) the average of body weight was 29.86 and 49.22 kg for Balady and Damascus goats, respectively. Analysis of variance indicated that breed had highly ($P < 0.01$) significant effect on LBW. Regarding to the effect of heat stress on LBW, exposure to solar radiation for 4 days declined LBW to 29.01 and 47.58 kg for Balady and Damascus goats, respectively. The rate of change in LBW recorded -2.85 and -3.33% for Balady and Damascus goats, respectively. This result revealed that the rate of decrease was higher in Damascus compared to Balady breed. Similar results reported by Khalil *et al.* [16] who found that the prolonged exposure to solar radiation for 12 hr increased the loss in LBW and increased PCV in local and crossbred sheep. Hafez [17] attributed the loss of body weight during exposure to solar radiation to the increase in energy expended for heat dissipation through respiratory evaporation and subsequently to the reduction in the amount of water available for storage, while Acharya *et al.* [18] mentioned that feed intake decreased during exposure to heat stress. The distinct variation in ear dimension and area which reach 1.7, 1.4 and 1.6 times of Damascus ear length, ear width and ear area, respectively compared with Balady one. In the same context, Marai *et al.* [19] intimated that in coated animal ears and legs tended to dissipate heat during heat stress.

In this study results as shown in Table 2 confirm that Balady coat temperature was higher in all taken records compared with Damascus coat temperature during the same time within the same period. Also, data in Table 2 clarify that coat temperature increased significantly ($P < 0.01$) during mid-morning, while reach the minimum temperature during both morning and mid-night in both breeds. In the first period both breeds had no significant differences in coat temperature (33.8 and 33.2°C) during morning and during evening (33.0 and 33.1°C) for Balady and Damascus, respectively. while, Balady coat temperature increased about one degree centigrade during mid-day (35.7 vs. 34.8°C) then tended to decrease one degree centigrade during mid-night compared with Damascus one (35.7 vs. 34.8°C). During first and second periods of exposure to sunlight, black coat of Balady goats had higher temperature especially during mid-day (40.2 and 38.6°C) compared with light brown Damascus one (38.7 and 37.2°C) and that could be attributed to the color effect. In accordance, results obtained by Acharya *et al.* [18] and D'mel *et al.* [20] reported that coat color could affect thermoregulatory parameters. Moreover, Al-Tamimi [21] found that coat temperature increased ($P < 0.01$) significantly during noon in sun exposed groups of black Bedwin goat compared with morning time. This is in agreement with Shearer [22] who noted that goats with lighter coat color reflected more light and absorbed between 40 and 50% less radiation than those with dark coats. Accordingly, the hair color provides advantages to the Damascus breed.

Dorsal line representative by wither, back and rump positions had higher coat temperature compared with the lateral line representative by shoulder, mid-side and britch

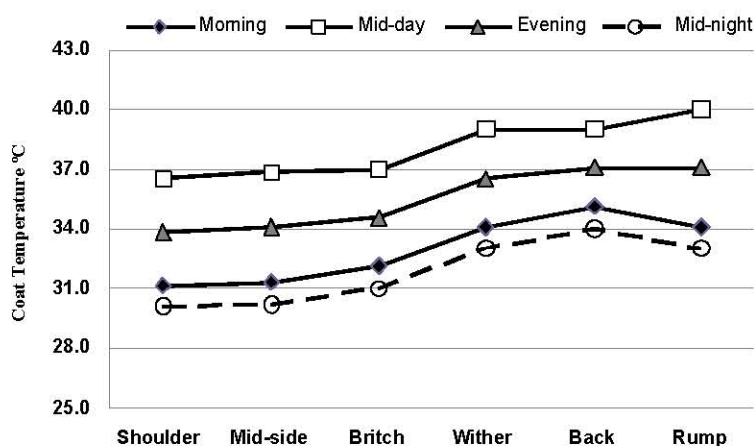


Fig. 2: Variation in coat temperature at long-term period among body positions during the day

Table 3: Characteristics of hair's scales in both Balady and Damascus goats

Fiber measurements	Balady	Damascus
Average fiber length (cm)	13.10	9.75
Average fiber diameter (FD, μm)	101.02 ^a	67.83 ^b
Average medullation (%)	78.86 ^a	41.36 ^b
Fibers diameter used in scan electron microscope (μm)	50.586	54.974
Scale area (μm)	84.013	73.302
Scale long (μm)	13.949	12.794
Scale width (μm)	26.850	24.793
Scale thickness (μm)	0.285	0.465
Scale height (μm)	0.204	0.418
Number of scales cover fiber circumference	4-5	2 - 3
Scales classification (Edge type)	smooth	smooth
Distance between scales	near to distant	near to distant
Appearance of scales	Wave	Wave

In each row means followed by different letters are significantly different

positions in all day times (Figure 2). Day time had significant effect ($P < 0.01$) on coat temperature, which reached the maximum temperature during mid-day then decreased to reach the minimal temperature during mid-night. Scales could be important in reflecting sunlight and that depending on the characteristics of the scales itself like scales patterns, area, thickness and serrations. Scales is responsible also for fiber brightness, handle and smoothness.

Results in Table 3 showed that Balady goats was slightly higher in scales dimensions (long, width and area) compared with Damascus goats, while Damascus goats had more thickness (1.63 times) and more height (2 times) than Balady one. Number of scales covers the fiber circumference increased in Balady goats and that could be related to the increase of fiber diameter in Balady hair with similarity in scales dimensions in both breeds (Table 3). Scales characteristics as well as edge type distance between scales and appearance found to be relatively

similar in both breeds, which give an impression that both breeds could live in the same environment.

Inner Coat: The important of inner coat (the fine, short and dense fibers) in thermoregulation become obvious in cold stress to keep body temperature inside [23, 24]. Figure (3) showed that Damascus goats had more potentiality to resist cold stress at early morning compared with Balady goats. Opposite trend was found between the subjective assessments of inner coat which tended to increase in the lateral line of body positions (SH, MS and Br) and coat depth which tended to increase in dorsal positions (Wth, Bk and Rp).

Coat depth was higher in Damascus goats (2.1cm) compared with Balady one (1.5cm). Hair long followed the same trend in Damascus and Balady one (13.1 and 9.75cm). Acharya *et al.* [18] reported that long haired goats tolerate radiant heat better than short haired goats.

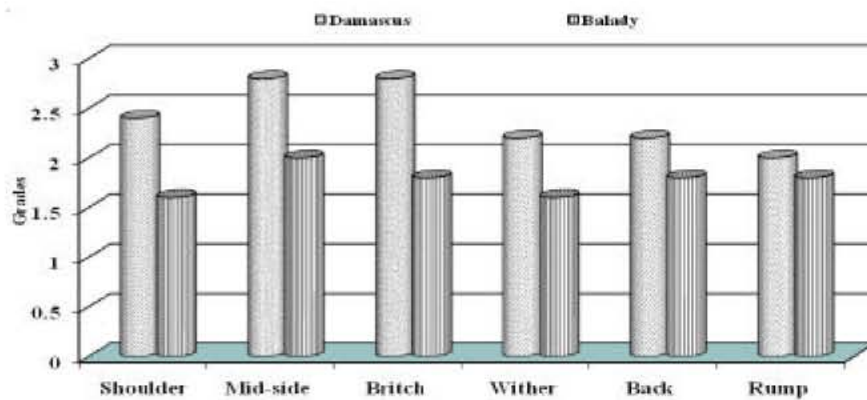


Fig. 3: Inner coat grading assessments in both Balady and Damascus goats

Thermoregulatory Responses: The average values of thermoregulatory parameters (RT and ST) during the experimental periods are presented in Table 2. At the start of study (pre-exposure to solar radiation) the overall mean values of RT and ST were 38.9 and 34.8°C vs. 39.0 and 35.2°C for Balady and Damascus breeds, respectively. Analysis of variance indicated that, breed has highly ($P < 0.01$) significant effect on RT and CT.

With respect to the time of day, results obtained in Table 2 revealed that there were obvious circadian variations in RT and ST in both breeds. These variations can be attributed to the differences in climatic conditions between times of the day (morning, mid-day, evening and mid-night), the highest values of these parameters were recorded at mid-day (THI= 87), while at mid-night, the values of RT and ST returned to the nearest former values at morning measure. Finch [25] explained that, at night the heat flow reverses and stored heat in the animal is dissipated back to the environment and then RT and ST falls. Similar results reported by Sleiman and Abi-Saab [26] who found that body temperature in Awassi, Finn Landrace (F), Texel (T) and FT crosses of sheep was slightly lower in the morning compared to the afternoon and during the three seasons (fall, spring and summer). Keskin *et al.* [27] found that season and hour of day affect on thermoregulatory parameters (RT, RR and HR) in different goat genotypes.

Regarding to the effect of heat stress, at the 2nd day of exposure to solar radiation (short-term) the overall means of RT and ST were found to be significantly higher ($P < 0.01$) compared with pre-exposure to solar radiation. The overall means of RT and ST at the end of short-term heat stress recoded (39.3 and 36.1°C vs. 39.5 and 35.2°C) for Balady and Damascus breeds, respectively. The rate of change was (1.18 and 3.73 % vs. 1.28 and -0.20 %), respectively. The prolonged of exposure to solar radiation

(4 days) increased significantly ($P < 0.01$) RT and ST and their values reached to (39.6 and 36.9 °C vs. 39.7 and 37.8°C) for Balady and Damascus breeds, respectively. The rate of change was (1.8 and 6.03 % vs. 1.7 and 7.3 %), respectively. These results indicated that RT and ST was much higher ($P < 0.01$) with prolonged exposure to solar radiation in both breeds. Our results are agreement with those obtained by Al-Tamimi [28] who found that RT, ST, RR and HR were higher in Damascus kids when exposed to day time solar radiation compared to the control group. In both breeds, during sudden (short-term) and prolonged exposure to solar radiation had a marked effect on RT and ST in each measure from morning till mid-night depending on THI value. The maximum shift was recorded on mid-day followed by evening times. The rate of increase at mid- day measure during short-term heat stress recorded (1.1 and 3.8°C vs. 1.0 and 2.9°C) in RT and ST for Balady and Damascus breeds, respectively. The corresponding values at evening measure were (0.62 and 1.10°C vs. 0.46 and 0.90°C) for Balady and Damascus breeds, respectively. These results indicated that the heat load was higher at mid-day measures compared with evening measures in both breeds but Balady breed had the wider shift. Similar results reported by McManus *et al.* [29] who found that, significant differences between morning and afternoon were noted for RT, ST, RR and HR in Brazilian sheep, being lower earlier in the day when temperatures decreased and humidity increased. These differences could be attributed to climatic differences.

The rate of increase at mid- day measurements during long-term heat stress recorded (0.78 and 0.8°C vs. 1.06 and 0.38°C) in RT and ST for Balady and Damascus breeds, respectively. The corresponding values at evening measure were (0.4 and -0.3°C vs. 0.58 and -0.2°C) for Balady and Damascus breeds, respectively. These results indicated that the heat load was higher at mid-day

measures compared with evening measures in both breeds but Balady breed had lower values. This result evidenced that Balady breed became more tolerate and experiencing in resistance to heat stress at long period. Previous reports by Al-Tamimi [21] and Augustinsson *et al.* [30] demonstrated that prolonged heat stress elevated RT in Bedwin goat kids experiencing heat stress. From the above results, both breeds were experiencing to heat stress when they reached to evening measures. The results obtained in Table 2 revealed that the maximum RT for Balady and Damascus breeds was 40.0 and 40.3°C (day 4 at mid-day). This result indicated that the prolonged and continuous high THI caused a significant rise in RT in both breeds and this indicating that the animals' heat loss mechanisms could not compensate fully for the excessive heat load i.e. heat gain exceeded heat loss.

Concerning of recovery period (Period III), animals in both breeds were shaded and showed that lowest means for RT and ST at all times measurements compared to the means of these parameters at short and long term exposure to solar radiation. The overall means of RT and ST were (38.84 and 35.9 vs. 39.32 and 36.62°C) for Balady and Damascus breeds, respectively. Table 2 implying the compensatory backshifts as percentage in RT and ST to compare the extent thermo-tolerance by Balady and Damascus breeds. These percentages were 103.4 and 84.7 % vs. 56.25 and 53.7 % in RT and ST for Balady and Damascus breeds, respectively. These results indicated that Balady goat appears to have the greater extent of thermoregulatory ability proven by fast adjustment of RT and ST to resistance short and long-term exposure to solar radiation. Finally, climatic conditions, time of the day, duration of heat stress and breed type were has highly ($P < 0.01$) significant effect on RT and ST.

Cardio-respiratory Responses: The average values of cardio-respiratory parameters (RR and HR) are presented in Table 4. At the start of study (pre-exposure to solar radiation) the overall mean values of RR and HR were (29.3 rpm and 63.3bpm vs. 32.2rpm and 66.8bpm) for Balady and Damascus breeds, respectively. Silanikove [31] classified the severity of heat stress to respiratory rate, where a frequency of 40-60 mov/min characterized low stress, 60-80 mov/min medium- high stress, 80-120 mov/min high stress and above 200 would be severe stress in sheep. By this classification, the animals in the present study were under high stress and medium-high stress at mid-day and evening measures during short- and long-term exposure to solar radiation.

Regarding to the effect of heat stress, the rate of change in RR at short- and long-term heat stress recorded (102.38 and 113.31% vs. 108.69 and 121.12%) for Balady and Damascus breeds, respectively. The corresponding values for HR were (2.2 and 3.8 % vs. 2.5 and 4.3 %) for Balady and Damascus breeds, respectively. Previous studies reported that, during heat stress evaporative heat loss via respiration rate can be greater for exotic breeds [32, 33, 34, 35] and this occurrence also probably reflects the greater engagement of heat loss mechanisms for the less-adapted breeds. Macfarlane *et al.* [36] revealed that RR of the adapted sheep in subtropical areas was lower than that of the foreign breeds. When these animals were exposed to solar radiation, the foreign breeds indicated more increase in RR compared with the adapted ones.

Regarding to the effect of the time of day, results obtained in Table 4 revealed that there were obvious circadian variations in RR and HR in both breeds. These variations can be attributed to the differences in climatic conditions between times of the day (morning, mid-day, evening and mid-night), as seen in the Table, RR recorded the highest values at mid-day and evening measures, while at mid-night measure RR returned to the nearest former values at morning. These results was agreement with those reported by Darcan *et al.* [37] who found that during morning measurements, RR and HR were found to be similar in cooled and non-cooled goats, while the difference was higher in the non-cooled group for afternoon measurements. Also, Darcan [38] showed that under the same conditions, the pulse and respiration rates increased when the ambient temperature rose up to 30°C. Regard to the decline in HR at mid-day measure during short and long exposure period in both breeds may be due to the increase in blood volume and high peripheral blood flow (vasodilation) as reported by Beatty [39] or at very high temperature, the HR decrease due to a decrease in the metabolic rate [40]. This was unexpected as others have reported increase in HR due to heat stress [28, 29].

Concerning of recovery period (Period III), animals in both breeds were shaded and showed that lowest means for RR and HR at all times measurements compared to the means of these parameters at short- and long term exposure to solar radiation. The overall means of RR and HR were (34.6rpm and 68.7bpm vs. 38.65rpm and 70.7 bpm) for Balady and Damascus breeds, respectively. Table 4 implying the compensatory backshifts as percentage in RR and HR to compare the extent thermo-tolerance by Balady and Damascus breeds. These percentages were 18.19 and 8.53 % vs. 20.03 and 2.76%.

Table 4: Effect of short- and long-term exposure to solar radiation on mean diurnal respiration (RR, rpm) and heart (HR, bpm) rates of Balady and Damascus goats during summer season at northern Sinai

Periods	Time	Balady		Damascus	
		RR (rpm)	HR (bpm)	RR (rpm)	HR (bpm)
Period I	MO	24.4 ^a ±1.17	59.0 ^b ±1.10	26.2 ^b ±0.07	61.8 ^b ±1.56
Pre-exposure	MD	37.4 ^a ±0.60	63.8 ^{ab} ±1.28	40.0 ^a ±0.89	66.6 ^{ab} ±1.72
	EV	31.0 ^b ±0.84	64.4 ^{ab} ±1.81	35.6 ^a ±1.36	68.0 ^{ab} ±2.80
	MN	24.4 ^a ±0.68	66.0 ^a ±2.76	27.0 ^b ±2.41	70.8 ^a ±2.73
Overall mean		29.3 ^b ±0.92	63.3 ^b ±0.73	32.2 ^b ±1.06	66.8 ^b ±0.87
Period II	MO	32.8 ^a ±1.90	66.8 ^{ab} ±1.50	37.8 ^a ±1.50	67.0 ^b ±1.18
Short-term	MD	95.4 ^b ±4.24	59.8 ^c ±1.46	105.0 ^b ±5.34	65.8 ^b ±1.83
Heat stress	EV	64.0 ^c ±1.61	63.2 ^{bc} ±1.02	73.8 ^c ±4.46	66.8 ^b ±2.18
	MN	44.8 ^a ±1.85	69.0 ^a ±2.30	52.0 ^a ±2.24	74.4 ^a ±2.06
Overall mean		59.3 ^a ±3.93	64.7 ^b ±0.78	67.2 ^a ±4.32	68.5 ^b ±0.82
Period II	MO	43.4 ^a ±1.99	65.8 ^a ±1.99	53.0 ^a ±3.79	70.8 ^a ±1.02
Long-term	MD	102.6 ^a ±2.50	60.2 ^b ±0.97	118.8 ^a ±1.50	64.4 ^a ±1.86
Heat stress	EV	66.0 ^b ±10.33	67.4 ^a ±1.54	71.6 ^b ±7.57	71.6 ^a ±0.98
	MN	37.8 ^a ±1.28	69.2 ^a ±1.50	41.4 ^a ±1.90	72.0 ^a ±4.38
Overall mean		62.5 ^a ±4.49	65.7 ^b ±0.74	71.2 ^a ±4.99	69.7 ^b ±0.95
Period III	MO	31.2 ^a ±1.02	70.2 ^a ±1.56	40.0 ^a ±5.55	72.8 ^a ±3.01
Recovery period	MD	36.4 ^a ±2.54	64.8 ^b ±1.59	42.0 ^a ±2.09	67.8 ^a ±1.35
(Shaded)	EV	36.4 ^a ±2.16	68.0 ^{ab} ±0.63	37.2 ^a ±1.53	69.0 ^a ±1.34
	MN	34.4 ^a ±1.94	71.6 ^a ±1.72	35.4 ^a ±1.63	73.2 ^a ±3.88
Overall mean		34.6 ^a ±0.73	68.7 ^a ±0.63	38.7 ^a ±0.16	70.7 ^a ±0.93
Percent of compensatory		18.19	8.53	20.03	2.76

MO = morning, MD = mid-day, EV = evening, MN = mid-night

In each column means followed by different letters are significantly different, columns of overall mean in each period followed by different bold letters are significantly different

Table 5: Significant differences between breeds within periods of exposure and during the same day time on the studied physiological parameters

Time	Period	RT	ST	CT	RR	HR
Morning	Pre-exposure	NS	33.0-35.1**	NS	NS	NS
	Short-term	NS	NS	36.2-35.5*	NS	NS
	Long-term	NS	NS	NS	NS	NS
	Recovery	NS	NS	34.6-33.9*	NS	NS
Mid-day	Pre-exposure	39.2-39.4*	NS	NS	37.4-40.0*	NS
	Short-term	NS	38.8-37.1**	NS	NS	59.8-65.8*
	Long-term	40.0-40.3*	NS	38.6-37.2**	102.6-118.8**	NS
	Recovery	NS	38.6-37.2**	37.8-34.5**	NS	NS
Evening	Pre-exposure	39.0-39.2*	NS	NS	31.0-35.6*	NS
	Short-term	NS	NS	40.9-36.4**	NS	NS
	Long-term	NS	36.7-37.8**	37.2-34.6*	NS	NS
	Recovery	NS	NS	NS	NS	NS
Mid-night	Pre-exposure	NS	NS	32.3-33.3*	NS	NS
	Short-term	39.1-39.4*	NS	35.4-33.6**	NS	NS
	Long-term	NS	36.0-37.0*	35.6-34.3*	NS	NS
	Recovery	NS	NS	35.2-33.6*	NS	NS

* P<0.05, ** P<0.01, NS= Non Significant, means to the left always belongs to Balady goats

Results obtained from Table 5 make a clear impression about the real differences between breeds. Coat temperature differ significantly during exposed to sunlight because of the differences in coat characteristics like coat color, hair long, fiber diameter, medullated fiber percentage and scales dimensions. Rectal temperature

was very close and differences are not significant in most times which indicated that both breed had the potentiality to rise in hot climate. Damascus goats had a stable ST compared with Balady one, which increase when exposed to direct sunlight and decreased during morning and mid-night and that could be due to the black color effect.

While black coat isn't favorable because light coats provide maximum protection against radiant heat, while black skin is favorable because it could absorb any ultraviolet light, this may have penetrated the coat, thereby preventing damage to tissue proteins [41]. No significant differences found between breeds in both respiration rate and heart rate during morning, evening and mid-night in all studied periods.

CONCLUSION

Variations in all studied traits were significantly higher among periods of exposure and time of the day more than between breeds. The role of coat in thermoregulation found to be clear at mild and moderate heat stress. Both breeds had the potentiality to raise in semi-arid conditions. Presence of inner coat, coat depth, light hair color, long hair, ear size helps Damascus goats to be adapted to hot environment. Further study needs to investigate the role of hair scales in sun rays reflection.

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