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THE RELATIONSHIP BETWEEN COAT COLOUR AND THERMOREGULATION IN DROMEDARY CAMELS (*Camelus dromedarius*)

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ABSTRACT

There are many camel breeds existing in Saudi Arabia, where coat colour represents the main criteria to name the breed. Breeds colour has been indicated as an important influential factor for body temperature and heat tolerance in various farm animals. The present study was aimed to investigate the variation in thermophysiological responses and heat tolerance of four Saudi camel breeds. Sixteen dromedary bulls of native breeds (*Almajaheem, Almaghatir, Alsafrah, Alzargeh*) of 4 animals each with mean body weight of 250±10 kg and 18 months of age were used in this study. Exposure of camel breeds to the hot summer (40°C) compared to spring (21°C) natural environmental conditions resulted in variable breed-dependent thermophysiological responses. The observed percentage increase in rectal temperature (Tr.) and respiratory rate (RR) due to summer heat exposure were highest in *Almaghatir* and *Alsafrah* breeds, respectively and lowest in *Alzargeh* breed. On the other hand, the percentage increase in packed cell volume (PCV) was highest in *Almajaheem* and *Alzargeh* breeds and lowest in *Alsafrah* and *Almaghatir* breeds. Further, all breeds have showed heat tolerance coefficient of 90% or more, where *Alzargeh* proved to be the best heat tolerant camel breed followed by *Almajaheem*, then *Alsafrah* and finally *Almaghatir*. The obtained results indicate that coat colour do not influence heat tolerance in camels. Nevertheless, further studies are needed to explore the role of breed variation in the structure of insulating coat and optical properties of coat hair on thermoregulation and heat tolerance of camels.

Key words: Camel, breed, coat colour, heat tolerance, thermoregulation

The world camel population is regularly increasing with a yearly growth of 3.4% (Faye *et al,* 2011). Saudi Arabia belongs to the countries with regular growth of camel population. The coat colour represents the main criteria to name the breed in Saudi Arabia (Faye *et al,* 2011). Accordingly many breeds are identified in Saudi Arabia including *Almajaheem* (black), *Almaghatir* and *Alawark* (white), *Alhomor* (brown), *Alsafrah* (dark brown), Alshaele (grey to brown red), *Alawadi* (red to white), *Alsaheli* (red), *Alhadhana* (yellowish to red), *Asail* (yellow to brown) and *Alzargeh* (blue grey).

Solar radiation considerably increases the environmental thermal load on the animal during summer months (Spiers, 2012). Coat hair colour (i.e. fractional reflectivity of the coat) has been directly related to the amount of the absorbed or reflected radiation, and thus the heat exchange between the animal and the surrounding environment (Gerken, 2010). There are growing body of evidence that during exposure to direct solar radiation dark-coloured coat absorbs more energy from the visible portion of the solar radiation than light-coloured coat, while in the absence of direct solar radiation the energy from the invisible (i.e. infrared) portion of spectrum is completely absorbed irrespective to coat colour (da Silva *et al,* 2003; McManus *et al,* 2011). It has been reported that susceptibility to heat stress in individual animal is determined by many factors including previous exposure to heat stress, temperature, species, sex and condition score (Brown Brandl, 2009). Energy exchange has been reported to be affected by skin and coat properties such as heat absorption, density, depth, diameter and colour (Bianchini *et al,* 2006; Bertipaglia *et al,* 2007). Breeds colour has been indicated as an important influential factor for body temperature and heat tolerance (da Silva *et al,* 2003; Otoikhian *et al,* 2009; McManus *et al,* 2011). In the tropics, the pigmentation of the skin is essential in protecting deep tissues against excess solar radiation (Castanheira *et al,* 2010), where light coats are the most desirable under such conditions (Alamer, 2006; McManus *et al,* 2009a; Otoikhian *et al,* 2009) compared to dark coats which is known to gain more heat load from solar radiation (Bianchini *et al,* 2006). Skin characteristics (thickness, colour,

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sweat glands) and coat characteristics (angle to the skin surface, texture, intensity, diameter and length) determine the protective properties through affecting the routes of heat exchange (conduction, convection, radiation, evaporation) between the animal and the environment (da Silva, 2000). Genetic role have also been reported in cattle, where genes responsible for the expression of short coats in Crioula breeds have shown to determine part of their heat tolerance (Olson *et al,* 1997; Olson *et al,* 2003).

Heat tolerance and adaptation capacity to hot environments have been evaluated using physiological parameters including respiration, heart rate, body and skin temperatures, sweating rate, packed cell volume, potassium content in erythrocytes, individual heat tolerance coefficient, hormonal secretion and decreased rate of production (Baccari, 1989; Marai and Habeeb, 2010; Castanheira *et al,* 2010; Li *et al,* 2011; Charoensook *et al,* 2012).

Despite the reported differences in the phenotypic coat colour of camel breeds existing in Saudi Arabia (Faye *et al,* 2011); there is no single report on heat tolerance variation between these breeds. Therefore, this study has been designed and conducted with the aim of exploring thermophysiological responses and heat tolerance of four Saudi camel breeds.

Materials and Methods

This study was conducted during spring (21°C) and summer (40°C) seasons at Al-Kharj region, Kingdom of Saudi Arabia. Sixteen dromedary bull camels of native breeds (*Almajaheem*, *Almaghatir*, *Alsafrah*, *Alzargeh*), 4 animals each, with mean body weight of 250±10.5 kg and 18 months of age were used in this study. Animals were housed as a group in a partially shaded pen with open yard, fed twice a day at 07.00 and 16.00 hours, and had free access to clean tap water.

Ambient temperature (T_a), relative humidity (RH), solar radiation and wind velocity were measured at 3 hours intervals for 2 successive days. Ambient temperature and RH were recorded using 2 data loggers (HOBO Pro Series data logger, Model H08-032-08, ONSET Co., Southern MA, USA) placed inside the pens. Thereafter, temperature-humidity index (THI) was calculated according to LPHSI (1990). Solar radiation and wind velocity were recorded using black globe temperature and anemometer (Wilh. Lambrecht GmbH, Gottingen, Germany), respectively.

Respiratory rate was counted at the space from 9^{th} to 11^{th} rib or from 3^{rd} to 6^{th} intercostal space using stethoscope (Littmann Stethoscope, USA) and expressed as breath/minute. While, a digital thermometer (ARTSANA, Grandate Co, Italy) measuring to the nearest 0.1ºC was used for measurements of rectal temperature (T_r). Body surface temperature (T_s) was recorded using a forward-looking and automatically calibrating thermal infrared camera (VisIR-Ti200 infrared vision camera, Thermoteknix Systems ltd, Cambridge, UK) placed perpendicularly and approximately 150 cm from camel's surfaces. This camera were equipped with 25° lens, 1.3 M pixel visible camera, and LCD touch screen, and have a 7.5–13 μm spectral range, and thermal accuracy of ± 2°C in addition to thermo-electrically cooling systems. After capturing, thermo-grams were stored inside a 250 MB internal memory, readout and analysed using a special thermo-grams analysis program (TherMonitor, Thermoteknix Systems ltd, Cambridge, UK). For all thermo-grams, a rainbow colour scheme was chosen. Thermo-grams were analysed by defining the body surface circumscribed by hand with the software polygon function. The software then gave back the average surface temperature (T_s). Heat tolerance coefficient (HTC) was calculated according to Iberia heat tolerance test developed by Rhoad (1944) using the following equation: HTC (%) = 100 – 10 (average T_r after exposure – normal control T_r).

Blood samples were collected by jugular venipuncture using 6 ml vacutainer tubes coated with sodium fluoride as anticoagulant. The samples were placed immediately on ice. Packed cell volume (PCV) was determined from whole blood shortly after collection.

The collected data were analysed using Proc GLM; the general linear models (GLM) procedure for analysis of variance (ANOVA) of Statistical Analysis System (SAS, 2003). Statistical means were compared using Duncan's multiple range test (DMRT). The overall level for statistical significance was set at $P<0.05$. All values were presented as least square means ± standard error of the means (LSM ± SE).

Results

Climatic data

The climatic data prevailed during this study is shown in table 1. Ambient temperature (T_a), black globe temperature and temperature humidity index (THI) were significantly ($P<0.001$) higher, while relative humidity (RH) was significantly (P<0.001) lower during the summer compared to spring season. Wind velocity did not vary significantly between the two seasons.

Table 1. Climatic data prevailed during the experiment.

Climatic parameter	Spring	Summer	P value
Ambient temperature (°C)	21.38±0.21	39.85±0.20	<0.001
Relative humidity (%)	33.93±1.33	9.20±0.16	<0.001
Black globe temperature (°C)	23.01±0.57	50.05±1.17	<0.001
Wind velocity (m/s)	3.23±0.14	2.93±0.21	0.270
Temperature humidity index (THI)	65.82±0.20	80.89±0.17	<0.001

Thermophysiological responses

Table 2 shows the thermophysiological responses of the studied camel breeds during the exposure to the hot summer conditions. Exposure of camel breeds to the hot summer (40°C) compared to spring (21°C) natural environmental conditions resulted in variable breed-dependent thermophysiological responses. Where, the observed percentage increase in rectal temperature (Tr) and respiratory rate (RR) due to summer heat exposure were highest in *Almaghatir* and *Alsafrah* breeds, respectively and lowest in *Alzargeh* breed. On the other hand, the percentage increase in packed cell volume (PCV) was highest in *Almajaheem* and *Alzargeh* breeds and lowest in *Alsafrah* and *Almaghatir* breeds. The body surface temperature (T_s) was increased significantly (P<0.001) in all studied breeds, with the lowest percentage increase (+32.07%) observed in *Almajaheem* breed. The observed thermophysiological responses indicate that *Alzargeh* and *Almajaheem* Suadi camel breeds have higher adaptation capacity to hot environments than *Alsafrah* and *Almaghatir* breeds.

Heat tolerance

All studied camel breeds showed heat tolerance coefficient of 90% or more (Table 3). *Alzargeh* breed proved to be the best heat tolerant Saudi camel breed followed by *Almajaheem*, then *Alsafrah* and finally *Almaghatir*.

Discussion

Camelus dromedarius are one of the largest terrestrial mammals that inhabit arid and semi-arid environments. Although some aspects of their thermoregulation are well documented (Schroter *et al,* 1989; Al-Haidary, 2001; Al-Haidary, 2006a, b), little is known about the role of their coat colour on the thermophysiological responses to heat stress.

Table 2. Thermophysiological responses of Saudi camel breeds exposed to heat stress.

Breed	Spring (21 °C)	Summer (40 °C)	% Change	P value
PCV				
Almajaheem	26.75±0.78	32.13±0.80	+20.11	0.003
Alzargeh	25.38±0.43	29.88±0.63	+17.73	0.001
Alsafrah	24.33±0.44	26.17±2.21	+7.56	0.461
Almaghatir	24.75±0.72	26.17±3.17	+5.74	0.632
T_r				
Almajaheem	37.88±0.05	38.30±0.09	+1.11	0.006
Alzargeh	37.98±0.06	38.15±0.34	+0.45	0.629
Alsafrah	38.03±0.08	38.73±0.39	+1.84	0.092
Almaghatir	37.85±0.09	38.87±0.38	+2.69	0.030
RR				
Almajaheem	14.74±1.47	17.86±0.66	+21.17	0.192
Alzargeh	15.17±1.45	17.63±1.85	+16.22	0.406
Alsafrah	12.62±0.23	19.66±1.23	+55.78	0.030
Almaghatir	14.52±0.77	19.10±0.22	+55.03	<0.001
T_s				
Almajaheem	30.25±1.45	39.95±0.12	+32.07	<0.001
Alzargeh	25.90±0.20	38.90±0.51	+50.19	<0.001
Alsafrah	26.25±0.95	40.85±1.15	+55.62	0.010
Almaghatir	25.35±0.65	39.30±0.97	+55.03	<0.001

PCV = packed cell volume; T_r = rectal temperature; RR = respiration rate; T_s = skin temperature

Table 3. Heat tolerance coefficient of the studied Saudi camel breeds.

	Almajaheem	Almaghatir	Alsafrah	Alzargeh	N
Heat tolerance (%)	95.8	89.8	93.0	98.3	4

The calculated THI value during summer season was 80.89±0.17 (Table 1). Excessive solar heat stress at the geographical region of Saudi Arabia has been previously recognised (Al-Haidary, 2006a). The THI index was constructed originally via Thom (1959) to estimate the environmental severity on the animals. This index has been utilised for more than four decades to assess heat stress in farm animal, using the integrative effect of Ta and RH as a one-dimensional approach (Hahn *et al,* 1998, Marai and Habeeb, 1998, Marai *et al,* 2001). In 1998, Hahn *et al* have classified THI values for dairy cattle as follow; up to 74 as "normal", from 75 to 78 as "alert", from 79 to 83 as "danger", 84 and more as "emergency". Therefore, camels used in this study were under comfortable environmental conditions during the spring season (THI = 65.82±0.20) and were exposed to heat stress during the summer season (THI = 80.89±0.17).

Exposure of camel breeds to heat stress conditions resulted in variable breed-dependent thermophysiological responses. Rectal temperatures (Tr.) exhibited higher percentage increases during heat stress condition compared to comfortable conditions. These increases were highest in *Almaghatir* and *Alsafrah* breeds and lowest in *Almajaheem* and *Alzargeh* breeds (Table 2). In response to the increased thermal load, noticeable divergences in several thermophysiological measurements including PCV, RR, as well as T_s were occurred in all camel breeds (Table 2). The percentage increase in packed cell volume (PCV) was highest in *Almajaheem* and *Alzargeh* breeds and lowest in *Alsafrah* and *Almaghatir* breeds (Table 2). The observed higher PCV values have been reported to be an adaptive mechanism of desert animals to provide the necessary water required for evaporative cooling process (Al-Haidary, 2004).The observed tachypnoea in camels indicated an increase in the respiratory evaporative cooling mechanism in order to counterbalance to some extent the elevated thermal load (Schroter *et al,* 1987). Using infra red thermograph (IRT), T_s exhibited noticeable percentage alterations (Table 2). The mammalian skin is an important pathway for heat exchange between the body surface and the environment. Surface temperature is the result of the adjustment of the skin blood flow that ends with regulation of the heat between the body core and skin (Habeeb *et al,* 1992). Thereby, blood is shifted all over camels' body to create a thermal gradient between their body and external environment to facilitate heat dissipation and hence thermoregulation (Curtis, 1983).

Breed-dependent differences of T_s were expected as the dark coat would accrue more solar heat load than the white coat under direct solar radiation (Walsberg, 1983; Gerken, 2010). Despite the previous reports on the influential role of breed colour on thermoregulation and heat tolerance (da Silva *et al,* 2003, Otoikhian *et al,* 2009, McManus *et al,* 2011), our results indicate that coat colour do not influence heat tolerance in camels. This is mainly due to fact that *Alzargeh* (blue grey) and *Almajaheem* (black) breeds had exhibited the highest heat tolerance coefficient (HTC) calculated according to Iberia heat tolerance test (Rhoad, 1944) under summer heat stress conditions (Table 3). The coat colour was considered one of many factors determining the solar heat load accrued by an animal. Skin pigmentation, coat structure, as well as low solar penetration and high air trapping within the coat hair may collectively play an essential role in protecting deep tissues, and subsequently mitigating the effect of high summer solar radiation (Alamer, 2006; Bianchini *et al,* 2006, McManus *et al,* 2009b, 2011, Antonini, 2010, Gerken, 2010, Castanheira *et al,* 2010). Nevertheless, further studies are needed to explore the role of breed variation in the structure of insulating coat and optical properties of coat hair on thermoregulation and heat tolerance of camels.

Conclusion

Although coat colour did not prove to influence heat tolerance in camels, further studies are needed to explore the role of insulating coat structure and optical properties of coat hair on thermoregulation and heat tolerance of camels.

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