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The Effects of Skin Pigmentation on Physiological Factors of Thermoregulation and Grazing Behaviour of Dairy Goats in a Hot and Humid Climate

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ABSTRACT : The aim of this study was to understand the effects of skin pigmentation on physiological parameters of thermoregulation and grazing behaviour of dairy goats in a hot and humid climate. The study used 26 crossbred Saanen yearling goats (95% Saanen+5% Local Hair Breed). The animals were raised at semi-intensive private farms in Adana (36 59' N, 35 18'E). Groups were selected 2 d before the start of observations. Goats were categorized as predominantly pigmented (P) skin and unpigmented (UP) skin. All observations and measurements were collected on grassland during the grazing period of June and July 2007 (60 d). Air temperature and relative humidity were recorded at 10 min intervals by a portable data logger. The physiological data (rectal temperature, respiration and pulse rate, and skin temperatures from head and udder) were recorded twice weekly in the morning (07:00-08:00); at midday (13:00-14:00); and in the evening (18:00-19:00). Additionally, the activity of the animals was observed and classified (eating, ruminating, drinking, standing, walking, lying) for 12 h during the day twice weekly, using a portable camera system linked directly to a computer. Panting behaviour was also observed. According to the THI values, the experimental goats were subjected to stressful conditions. The pigmented goats had significantly lower rectal temperatures (39.68 vs. 29.89°C), pulse rate (74.08 vs. 84.10 beat/min) and respiration rate (65.65 vs. 88.23 breath/min.) compared with unpigmented goats at midday when the THI exceeded 92. The rectal, head and udder temperatures, pulse and respiration rates of the non-pigmented group exceeded 40°C, 37°C, 37.5°C, 84 beats/min and 78 breaths/min, respectively. Higher activity was observed among pigmented compared with unpigmented goats. Unpigmented goats grazed (4.3 vs. 5.6 h), ruminated (2.0 vs. 2.4 h), and stood (0.8 vs. 1.2 h) less, but lay down (2.2 vs. 1.8 h) more than pigmented goats. The data obtained in this experiment support the hypothesis that unpigmented goats are more adversely affected by climatic stress, likely due to their decreased activity and increased water consumption, as demonstrated by previous studies. (**Key Words** : Skin Pigmentation, Heat Stress, Physiological Factors, Grazing, Behaviour Goat)

INTRODUCTION

Exposure to hot and humid weather affects the physiology (Silanikove, 2000; Pongpiachan et al., 2003; Kamiya et al., 2006a; Darcan and Guney, 2008), performance (Kamiya et al., 2006b; Darcan et al., 2008; Darcan and Cankaya, 2008) and also welfare (Devendra, 1987; Blackshaw and Blackshaw, 1994; Darcan et al., 2008) of farm animals. Korde et al. (2007) reported that, an adaptive response of acid-base regulation was determined to long term (21 days) exposure of buffalo calves to hot-dry (THI 80) and hot-humid (THI 84) conditions. Higher rectal temperature and respiratory rate was recorded under hot-humid exposure compared to hot-dry. Significant reduction in the rectal temperature and respiratory rate on day 21 of hot-dry exposure indicated early thermal adaptation compared to hot-humid. Decreasing rectal temperature and respiratory rate from day 1 to 21 was associated with concurrent decrease in blood pH and pCO2. Increased plasma chloride concentration with low base excess in blood and in extracellular fluid suggested compensatory response to respiratory alkalosis. Reduced fractional excretion of sodium with increased fractional excretion of potassium and urine flow rate indicated renal adaptive response to heat stress. As it is well known that, respiration rate and core body temperature increase during heat exposure (Wise et al., 1988; Ominski et al., 2002). When subjected to heat stress, homoeothermic animals employ several thermoregulatory mechanisms to offset heat gain by

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Table 1. Climatic data and THI of each of the experimental pens during trial

Traits	Hours	Average values
Air temperature (°C)	07:00-08:00	32.25±0.16
	13:00-14:00	37.15±0.21
	18:00-19:00	35.23±0.12
Relative humidity (%)	07:00-08:00	62.88±0.56
	13:00-14:00	67.43±0.98
	18:00-19:00	64.89±0.56
THI	07:00-08:00	84
	13:00-14:00	92
	18:00-19:00	89

an equivalent loss to maintain their core body temperature and attain thermal equilibrium. The first means of protection is provided by the coat, both from its colour and physical characteristics. The anatomy and physical chemistry of the surface is structurally adapted to each environment.

The pigmentation of many animals is adapted to their environment and aids in their survival. The major animal pigments are the haemes (red) of blood haemoglobin, the carotenes, melanin (black and brown), and guanine (white and iridescent). Production of melanin is dependent on UV or sun exposure, and is a natural protective mechanism of the skin (Seo et al., 2007). However, the literature on skin pigmentation and adaptation is scant and does not provide a holistic view of the effects of skin pigmentation on physiological parameters and grazing behaviour of dairy goats in a hot and humid climate.

The response of a conscious subject to stress is not limited to alterations of physiological parameters, but also involves appropriate behavioural adjustments. Domestic ruminants are mainly diurnal in their habits, being active during the day and resting at night. However, during hot weather, grazing ruminants tend to lie down and to reduce their locomotion during the day. Seeking shade, particularly during the heat of the day, is a conspicuous form of behavioural adaptation in these areas (Finch, 1984). This range of behavioural response affects the heat exchange between the animal and its environment by reducing heat gain from radiation, and increasing heat loss via convection and conduction.

Under high heat stress, some breeds and their crosses have better heat regulatory capacities, due to differences in metabolic rate, food and water consumption, sweating rate, and coat characteristics and colour. Also, because they have a higher heat loading at the skin, they must evaporate substantially more sweat than the others to maintain normal body temperatures (Blackshaw and Blackshaw, 1994). Determining their performance in different conditions will provide important data for planning future breeding programmes. However, very few studies have been carried out on the adaptive performance parameters of exotic breeds in hot and humid conditions. For this reason, this study was carried out to determine the effects of skin pigmentation on the physiological factors of thermoregulation and grazing behaviour of dairy goats in a hot and humid climate.

MATERIALS AND METHODS

The study used 26 crossbred Saanen yearling goats (95% Saanen+5% Local Hair Breed), raised under semi-intensive conditions at private farms in Adana (36 59' N, 35 18'E). The animals had an average body weight of 46 kg and body condition score between 2 and 3. Groups were selected 2 d before the start of observations. Goats were categorized as predominantly pigmented (P) skin and unpigmented (UP) skin. The pigmentation was measured from skin all over the body and the animals were examined individually. They grazed together on the natural grassland of hilly areas from 06:00 h to 19:00 h. All observations and measurements were collected on the grassland during grazing. They were kept in a semi-open barn overnight. All animals were fed as a group on concentrate (12% crude protein and 2,300 kcal/kg ME), alfalfa hay and oats when they returned to the barn. Free access to water was provided during the grazing period. Treatments were applied for 60 d during June and July 2007. Air temperature and relative humidity were recorded at 10 min intervals by a portable data logger (Testo 950 humidity and temperature sensor). The principal climatic characteristic of Adana Province is high air temperature and humidity in the summer season. The average daily temperature was 36.2°C, while the highest and lowest temperatures were 42°C and 25.1°C in July, respectively. Average relative humidity and wind speed were observed as 72.2% and 1.0 km/h during the trial, respectively. The climatic data such as air temperature, relative humidity and Thermal Heat Index (THI) of the trial are shown in Table 1.

THI was used as an indicator of thermal comfort for dairy goats and was calculated as follows (Tucker et al., 2008):

$$THI = (1.8XT+32)-((0.55-0.0055)\times RH)\times(1.8XT-26))$$

where T is the air temperature (°C) and RH the relative humidity (%).

The physiological data (rectal temperature, respiration and pulse rates, and skin temperatures from head and udder skin) were recorded in the morning at 0700-0800, at midday at 13:00-14:00 and in the evening at 1800-1900 twice a week. Rectal temperatures were detected by digital thermometer, and the respiration and pulse rates were recorded using a stethoscope. Skin temperature was measured via infrared thermometer (Testo BP-960) at a

Table 2. Description of panting scores (Brown-Brandl et al., 2006)

Score	Description
0	Normal respiration, 60 or fewer breaths/min
1	Slightly elevated respiration, 60-90 breaths/min
2	Moderate panting and/or the presence of drool or small amount of saliva, 90-120 breaths/min
3	Heavy open-mouthed panting, saliva usually present, 120-150 breaths/min
4	Severe open-mouthed panting accompanied by protruding tongue and excessive salivation

distance of 8 cm from the head and udder skin. The activity of the animals was observed and classified as follows: eating, ruminating, drinking, standing, walking, and lying. Behavioural observations were recorded for 12 h during the day, twice a week, using a portable camera system linked directly to a computer. Panting behaviour was observed as well. Panting score is an effective management tool to assist in the assessment of stress levels due to heat in grain-fed cattle, and should be used as part of summer management. It has the potential to be used in the assessment of the welfare status of animals (Gaughan, 2003). The panting scores were assigned on the basis of visual observation of behaviour. A description of panting scores is given in Table 2 (Brown-Brandl et al., 2006).

Statistical analysis

Daily activities were analyzed with Student's *t*-test to determine the effect of skin type. Also, data were analyzed by analysis of variance of a completely randomized block design: $\hat{Y}_{ijk} = \mu + S_i + T_j + ST_{ij} + e_{ijk}$ where, $\hat{Y}_{ijk}$ is observation value (rectal temperature (RT), head skin temperature (HT), udder skin temperature (TT)); μ is the overall mean; S_i is the effect of the ith skin type (1 = predominantly pigmented skin, 2 = unpigmented skin), T_j is the effect of the jth time (1 = in the morning 07:00-08:00, 2 = at midday 13:00-14:00 and 3 = in the evening 18:00-19:00), ST_{ij} is the effect of interaction between skin type and time, and e_{ijk} = residual error. Duncan's multiple range test was then used to analyze these differences. Respiration rate (RR), pulse rate (PR) and panting score (PS) were analyzed using the Friedman test. Dunn's multiple comparison tests were applied to determine any further differences among the groups. All the computational work was performed by means of MINITAB V.13.20 statistical package program (MINITAB, 2000).

RESULTS AND DISCUSSION

Table 1 summarizes the climatic factors recorded during the experiment. Air temperature, relative humidity and THI were higher at midday (13:00-14:00) compared to morning (07:00-08:00) and evening (18:00-19:00). They rose during the day but declined at night. Silanikove (2000) and Avendano-Reyes et al. (2006) reported that the homoeothermic ability of dairy goats starts to be compromised when the Thermal Heat Index (THI) exceeds 80%. Silanikove (2000) reported that the THI is a good indicator of stressful thermal climatic conditions. THI values of 70 or less are considered comfortable, 75-78 stressful, and values greater than 78 cause extreme distress and animals are unable to maintain thermoregulatory mechanisms or normal body temperature. Based upon the THI values, the experimental goats were subjected to stressful conditions (i.e. 84 to 92, see Table 1) in this experiment.

Bianca and Kunz (1978) found that Saanen goats exposed to high environmental temperature increased their respiration rate tenfold from 26 to 261 breaths/min. Normal body temperature, respiration and pulse rates of Saanen goats in their comfort zone were recorded as 38.8°C, 25.3 breaths/min and 94 beats/min, respectively. The Saanen is particularly sensitive to strong sunlight and for this reason it is often continuously stall-fed in the tropics (Devendra,

Table 3. Physiological reactions of experimental goats during grazing period

Group	Hours	Rectal temperature (°C)	Pulse rate (beat/min)	Respiration rate (per/min)	HT (°C)	UT (°C)	Panting score
P	07:00-08:00	39.37±0.020 e	65.85±0.640 d	44.80±0.558 f	34.19±0.18 c	34.22±0.24 b	1.25±0.03 c
	13:00-14:00	39.68±0.033 bc	74.08±1.030 c	65.65±1.260 c	36.48±0.13 b	37.26±0.14 a	1.75±0.02 b
	18:00-19:00	39.62±0.024 c	74.00±1.003 c	59.15±1.490 d	32.67±0.32 d	32.89±0.43 c	1.25±0.06 c
UP	07:00-08:00	39.52±0.021 d	66.35±0.629 d	50.23±0.645 e	34.25±0.21 c	34.25±0.11 b	1.25±0.05 c
	13:00-14:00	39.89±0.036 a	84.10±0.477 a	88.23±1.115 a	37.16±0.33 a	37.49±0.21 a	2.50±0.04 a
	18:00-19:00	39.72±0.031 b	80.68±0.898 b	73.78±1.031 b	32.45±0.21 d	33.17±0.13 c	1.25±0.03 c
Effects							
Group		**	**	**	**	**	**
Hours		**	**	**	**	**	**
(G*H) Interaction		**	**	**	*	*	*

* $p<0.05$, ** $p<0.01$. P = Pigmented goats; UP = Unpigmented goats; HT = Head skin temperature; UT = Udder skin temperature.

Table 4. Daily activities and daily feed and water consumption of experimental goats during grazing period

Traits	P	UP
Grazing (h/12 h)*	5.8±0.8 a	4.3±0.2 b
Ruminating (h/12 h)*	2.4±0.2 a	2.0±0.6 b
Drinking (h/12 h)*	1.2±0.6 b	1.8±0.2 a
Walking (h/12 h)	0.8±0.5	0.9±0.3
Lying (h/12 h)*	1.8±0.4 b	2.2±0.8 a
Standing (h/12 h)*	1.2±0.2 a	0.8±0.4 b

P = Pigmented goats; UP = Unpigmented goats. * $p<0.05$.

1987). As seen in Table 3, heat stress (THI 84, 89 and 92) significantly increased the rectal temperatures, pulse and respiration rates of pigmented and unpigmented goats ($p<0.01$), which was consistent with previous studies (Darcan and Güney, 2002a; Darcan and Güney, 2002b; Darcan and Cankaya, 2008; Darcan and Güney, 2008; Darcan et al., 2008).

The pigmented goats had significantly lower rectal temperatures (39.68 vs. 29.89°C), pulse rate (74.08 vs. 84.10 beat/min) and respiration rate (65.65 vs. 88.23 breath /min) compared with unpigmented ones at midday when the THI exceeded 92. Rectal temperature, pulse and respiration rates are important indicators of thermal balance and might be used to evaluate the impact of heat stress (Spiers et al., 2004). Rectal, head and udder temperatures of unpigmented goats increased until midday and slightly decreased during the afternoon, while there were no significant differences between diurnal body temperatures (rectal, head and udder) of the pigmented goats. Avendano-Rayes et al. (2006) and Yousef (1985) reported that increased body temperature, pulse and respiration rates are a normal mechanism by which animals diffuse heat from their bodies to maintain thermoregulation in hot ambient conditions. In the present experiment, the rectal, head and udder temperatures, pulse and respiration rates of the non-pigmented groups exceeded 40°C, 37°C, 37.5°C, 84 beats/min and 78 breaths/min, respectively.

In all farm animals, only goats can maintain their rectal temperatures below 38.5°C, which is considered normal (Devendra, 1987; Avendano-Reyes et al., 2006). Their basal respiration rate is about 25-30 breaths per min (Silanikove, 2000) and basal pulse rate is about 65-80 beats per min (Devendra, 1987). Respiration rate measurement can provide reliable and practical information for estimating the severity of heat stress in farm animals (low: 40-60 breaths per min; medium high: 60-80 breaths per min; high: 80-120 breaths per min; and severe heat stress above 150 breaths per min) (Silanikove, 2000). Unpigmented goats suffer high stress levels according to observations by Silanikove (2000), and are affected by high ambient temperatures more than pigmented goats, because it is impossible to maintain their normal body temperature in such condition.

According to Heath et al. (2001), Coulter et al. (1988) indicated that thermographs utilise the measurement of infrared radiation to measure surface body temperatures. They can also be used as an indicator of the temperature of tissues deep under the skin as well as actual skin temperature. Head and udder temperatures of both groups had the same trends and rose to almost the same levels during daily heat exposure. Also, the other physiological parameters changed significantly. Thus the direct solar energy affected both groups to the same degree, but pigmented animals balanced the physiological parameters that are an important indicator of thermal balance and might be used to evaluate the impact of heat stress.

Panting scores are used especially for cattle, as indicated by Darcan et al. (2008). However, they can be useful for goats; in this study, unpigmented goats had higher scores compared to pigmented goats ($p<0.01$). Panting scores of the experimental goats were higher than reported by Darcan et al. (2008) due to the ambient conditions. The data of the present study were collected under direct exposure to solar radiation. Scores were highest at midday.

All groups had the same daily trend in panting score. Silanikove (2000) stated that as the temperature drops below 21°C for 6-7 h between 2200-0500, the animal has sufficient opportunity to lose all the heat gained from the previous day. These data indicate that pigmentation could have a beneficial effect on thermoregulation when thermal heat stress has negative effects on goats.

Ogebe et al. (1996) reported that, as temperature increased; less time was spent consuming food, probably to minimize or curtail body heat production and to keep the body cool. Hirayama and Katoh (2004), reported that, time spent eating in the heat treatment was the highest, while ruminating time was the lowest. Thus stressed goats ate more but ruminated less than non-stressed goats. More activity was observed among pigmented goats compared with unpigmented ones (Table 4). Unpigmented goats grazed (4.3 vs. 5.6 h), ruminated (2.0 vs. 2.4 h), and stood (0.8 vs. 1.2 h) less, but lay down (2.2 vs. 1.8 h) more than pigmented goats. These data matched with physiological values. Thus unpigmented goats were more stressed than the pigmented groups. Unpigmented goats spent more time drinking water on the grassland. Evaporative water loss from unpigmented goats was more due to heat stress than in the pigmented goats, as reported by Tucker et al. (2008), Ogebe et al. (1996) and Devendra (1987).

CONCLUSION

Physiologically, panting scores and also pulse and respiration rates were higher in unpigmented goats compared to pigmented goats. These parameters were related to thermoregulation. The data obtained in this experiment verified the argument that unpigmented goats are more adversely affected by climatic stress, probably due to their decreased activity and increased water consumption, which is consistent with previous studies. Furthermore these results demonstrate that pigmentation could be used as a selection criterion in a hot and humid climate. However, there is a need for further clarification of skin pigmentation effects on heat stress in goats in order to provide important data for future breeding programmes.

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