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THERMOREGULATION IN THE ONE-HUMPED SHE CAMEL *(Camelus dromedarius)*: DIURNAL AND SEASONAL EFFECTS ON CORE AND SURFACE TEMPERATURES

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ABSTRACT

The study was carried out at Maryout Research Station, 35 km to Southwest of Alexandria that belongs to the Desert Research Center (DRC), Egypt. The study was performed to evaluate the thermoregulatory ability of one-humped she camel (*Camelus dromedarius*) during summer and winter seasons. Five adult healthy she-camels aged 6-8 years with initial body weight recorded 522.00±3.52 and 613.00±6.63 kg for summer and winter seasons, respectively, were used. The animals were kept in outdoor pen (un-shaded).

Rectal (RT), skin surface (SST), surface coat (SCT) and mid-coat (MCT) temperatures were measured 3 times daily (6:00 am; 12:00 pm and 6:00 pm) during the ten middle days of each month during both summer (from June till August) and winter (from December till February). Ambient temperature and relative humidity were recorded at 06:00, 12:00 and 18:00 hr during summer and winter seasons.

Regarding the effect of season on RT, the results indicated that there were significant differences ($P<0.01$) between seasons. Average RT was 38.6 and 37.45 ºC during summer and winter seasons, respectively. In general, seasonal and diurnal variations in rectal temperature followed closely observed changes in the temperature-humidity index (THI).

Skin surface temperature (SST) varied between the selected sites over the animal's body and between seasons. The changes in SST at the selected sites were higher ($P<0.01$) under cold climatic conditions (winter) than warm climatic conditions (summer). These results indicated that SST was dependent on climatic conditions.

The results revealed that SST recorded highly ($P<0.01$) significant differences between hump (represent site exposed to sun) and abdomen (represent site not exposed to sun). The hump site was the warmest during summer (35.5 and 33.27 ºC) and winter (16.23 and 20.17 ºC) for SCT and MCT, respectively, whereas AB site recorded the lowest readings during summer (30.30 and 28.57 ºC) and winter (10.70 and 13.07 ºC) for SCT and MCT, respectively. The mid-coat temperature is less than surface-coat temperature in summer in order to decrease the transfer of heat from air to the skin. Meanwhile, the mid-coat temperature is more than surface-coat temperature in winter to minimize or prevent the dissipation of heat from the skin to the environment and preserve skin temperature as much as possible. The camels' coats, which are hairy rather than wooly in nature, create a favorable microclimatic buffer zone that separate the body surface from the surrounding harsh climatic conditions.

Keywords: She camel, dromedary, thermoregulation, diurnal rhythms, diurnal season effects.

INTRODUCTION

The camel is well suited to the harsh desert environments characterized by seasonal shortage of water and vegetation as well as

high ambient temperatures and other environmental stresses. This is because the camel is anatomically and physiologically equipped with adaptive homeostatic mechanisms (Eltahir *et al*., 2010) enabling it to survive, produce and reproduce, and to support human life in such arid 2
zones (Souilem and Kamel 2009).

The camel is peculiar in that it is a homeotherm, being able to maintain relatively constant body temperature independent of variations in the ambient temperature. On the other hand, it can vary its core temperature allowing it to rise in mid-day to reduce heat gain from the environment and to lower it at night to allow for passive heat loss, i.e. not water expensive. Diurnal variations in the rectal temperature of the camel were 2 ^{0}C in winter and 6 ^{0}C in summer (Schmidt-Nielsen 1964, Payne 1992).

In addition, the camel's coat which is more hairy than wooly create a favorable buffer zone that separate body surface from the surrounding climatic conditions (Gauthier-Pilters and Dagg 1981). Coat thickness varies, through growth and shedding, to cope with prevailing environmental conditions during the different seasons of the year (Wilson 1984).

The present study was intended to highlight the effects of seasonal and diurnal variations on core and surface temperatures of she camel, and as it relates to its thermoregulatory ability.

MATERIALS AND METHODS

Animals and management:

The study was carried out at Maryout Research Station, some 35 km south-west the city of Alexandria, Egypt. It involved five non-pregnant and non-lactating adult she-camels, 6-8 years old. Their initial body weight was 522.0±3.52 and 613.0±6.63 kg during summer and winter seasons, respectively. They were housed in an un-shaded yard for the duration of the experiment which extended over the summer months of June, July and August, and the winter months of December, January and February. Animals were fed maintenance rations composed of a pelleted commercial concentrate mixture, clover hay and rice straw. The proximate composition of feed ingredients was determined as per official procedures (A.O.A.C. 1990). Feeds were offered twice daily. Drinking water was offered ad lib once daily in the morning. Live body weights were recorded biweekly. The animals were clinically healthy and free from internal and external parasites.

Climatic data:

Climatic data were recorded during the middle ten days of each month and at three times daily, namely 06:00, 12:00 and 18:00 hr, and monthly averages were calculated. Measurements included ambient temperature (Ta, ^{0}C), relative humidity (RH, %) and solar radiation (SR) using automatic thermo-hygrometer and a black-bulb thermometer (HANNA instruments, Italy). Temperature-humidity index (THI) was calculated to portray the environmental heat load on the animal (Olson *et* *al*., 2002), where Ta is the ambient temperature and RH being a fraction (RH% / 100):

THI = 0.8 Ta + RH x [(Ta – 14.3) + 46.3]

If the THI value exceeds about 72, the animal will start to experience heat stress. This index was developed for dairy cows (and man), however, and its absolute values may not apply directly to camels especially with their known adaptive capacity to withstand heat stress. Nevertheless, it could still be a valid relative measure. Summer and winter monthly climatic data are summarized in Table 1 and monthly averages illustrated in Figure 1.

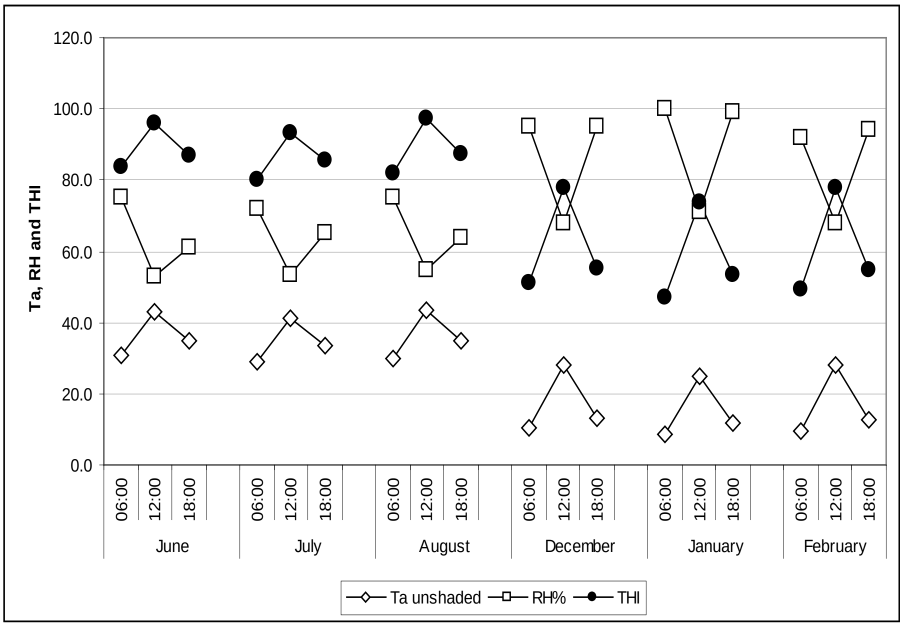


Figure 1. Average summer and winter diurnal variations of the climatic elements.

Animal measurements:

Rectal, skin and coat temperatures were measured at the same three times daily, i.e. 06:00, 12:00 and 18:00 hr. Rectal temperature (RT) was measured using a veterinary thermometer inserted 8 cm into the rectum and held pressed against the rectal wall. Skin surface temperature (SST) and surface coat (SCT) and mid-coat (MCT) were measured using a suitable thermocouple probe of a thermistor thermometer (McCaffrey *et al,.* 1979). Measurements were taken from seven regions: neck (NE), shoulder (SH), hump (HU), hip (HI), fore-limb (FL), hind-limb (HL) and abdomen (AB), and on both left and right sides of the body. Regional averages were calculated monthly for statistical evaluation.

Table (1): Summer and winter monthly and seasonal average ambient temperature, relative humidity and the calculated temperature-humidity index[1]

	Summer											
	June			July			August			Average		
	06:00	12:00	18:00	06:00	12:00	18:00	06:00	12:00	18:00	06:00	12:00	18:00
Ambient temp. Ta ^{0}C												
shaded	28.0	40.0	30.0	26.0	38.0	28.0	27.0	40.0	29.0	27.0	39.5	29.5
unshaded	31.0	43.0	35.0	29.0	41.0	33.5	30.0	43.5	35.0	30.0	42.5	34.5
RH%	75.0	53.0	61.0	72.0	53.5	65.0	75.0	55.0	64.0	74.0	53.8	63.0
THI[1]	83.6	95.9	86.9	80.1	93.4	85.6	82.1	97.2	87.5	81.9	95.5	86.6
	Winter											
	December			January			February			Average		
	06:00	12:00	18:00	06:00	12:00	18:00	06:00	12:00	18:00	06:00	12:00	18:00
Ambient temp. Ta ^{0}C												
shaded	9.0	23.0	11.0	7.0	22.0	10.0	8.0	22.5	10.5	8.0	22.5	10.5
unshaded	10.5	28.0	13.0	8.5	25.0	12.0	9.5	28.0	12.5	9.5	27.0	12.5
RH%	95.0	68.0	95.0	100.0	71.0	99.0	92.0	68.0	94.0	99.0	69.0	96.0
THI[1]	51.1	78.0	55.5	47.3	73.9	53.6	49.5	78.0	54.6	49.1	76.7	54.6

1 THI = (0.8*Ta) + (RH * (Ta-14.3) + 46.3) ,
where Ta is the unshaded ambient temperature and RH is a fraction (Olson *et al*., 2002).

Statistical analysis:

Means, standard errors, minimum and maximum values were calculated in a Microsoft Excel spreadsheet. Data were statistically analyzed using GLM procedures of SAS (Goodnight *et al*., 1986). Duncan's new multiple-range test (Duncan,1955) was employed to test differences between means.

RESULTS AND DISCUSSION

Environmental stress:

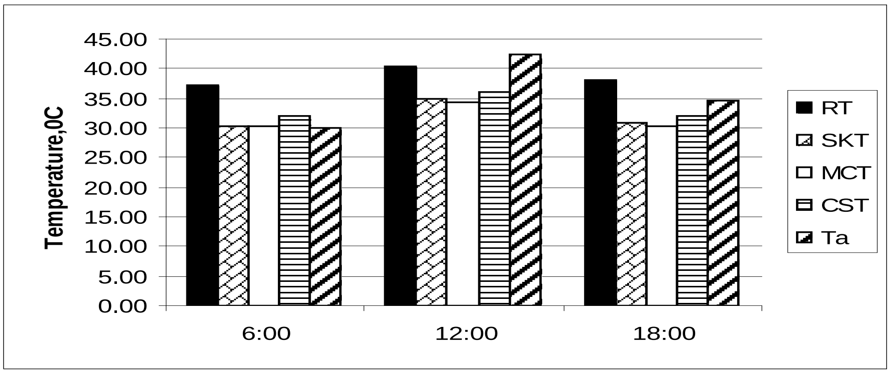
Summer and winter climatic variables are summarized in Table 1. Average diurnal variations are illustrated in Figure 1. Differences between shaded and unshaded ambient temperatures were 4.5°C and 3.0°C in summer and winter, respectively. On average, noon ambient temperature differences between summer and winter were 17.0°C shaded and 15.5°C unshaded measurements. Relative humidity was lower in summer than in winter, 53.8% vs 69.0%, respectively, and lower at noon than in the morning, and evening RH was intermediate. Also, calculated temperature-humidity index (THI) was maximum at noon, minimum in the morning and intermediate at 18:00 hr. It was much higher in summer than winter. In summer, THI was greater than 80 irrespective of the time of the day. In winter, it was 76.7 at noon and below 70 morning and evening. Although THI values of 72 or above indicate environmental stress in dairy cattle (Olson *et al*., 2002), this may not apply directly to the camel with its known was greater in summer than in winter and in the afternoon as compared to other times of the day.

Table (2): Mean ± SE of diurnal variations in rectal temperature (RT, ºC) of the one-humped she camel during summer and winter seasons.

Season	Month	Time of day (hr)			Mean ±SE
		06:00	12:00	18:00	
Summer	June	37.4	38.8	37.4	**37.86 [f] ± 0.148**
	July	37.2	39.1	38.2	**38.17 [e] ± 0.174**
	August	37.1	43.3	39.0	**39.80 [d] ± 0.580**
	Average	**37.23[c]**	**40.4[a]**	**38.2[b]**	**38.61[**] ± 0.300**
Winter	December	36.9	38.5	36.9	**37.43 [e] ± 0.274**
	January	37.0	38.3	37.5	**37.60 [d] ± 0.046**
	February	36.4	38.1	37.5	**37.33 [f] ± 0.157**
	Average	**36.77 [b]**	**38.30 [a]**	**37.30 [c]**	**37.45 ± 0.159**

a ,b and c as superscript in the same raw show significant differences among time of day; d, e and f as superscript in the same column show significant differences among months ; ** = P<0.01 between seasons

1. Summer:



2. Winter

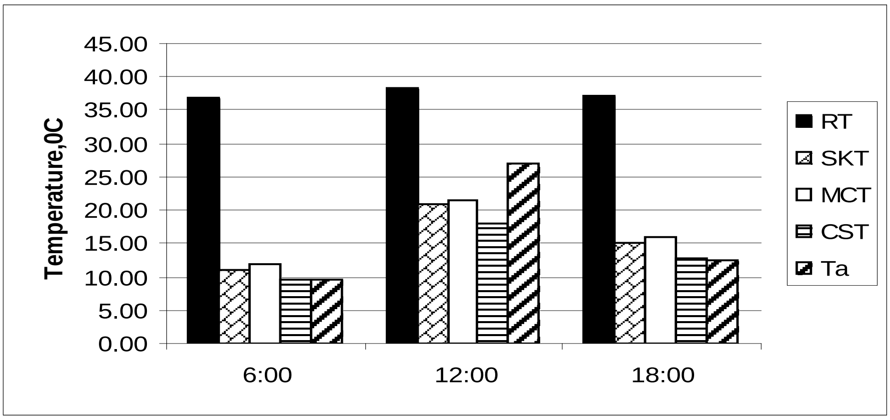


Figure 2. Average temperature gradients from rectal to skin, mid-coat, coat surface and ambient temperatures during summer and winter seasons at different times of the day

Noteworthy, except for the noon unshaded ambient temperature in summer, ambient temperatures were less than both rectal and skin surface temperatures (Tables 1, 2 and 3). This indicates that the she camel's passive heat dissipation was not hindered and the need for evaporative cooling was limited only to the relatively short periods of summer afternoons.

Table (3): Mean ± SE of diurnal variations in skin surface temperature (SST, ºC) at different skin sites of the one-humped she camel during summer and winter seasons.

Season	Time	Skin Sites							Mean ± SE
		NE	SH	HU	HI	FL	HL	AB	
Summer	06:00	29.9	30.50	31.2	31.0	30.3	31.1	27.6	**30.23^{f} ± 0.106**
	12:00	34.3	34.9	37.5	35.3	35.0	36.1	31.4	**34.93^{d} ± 0.158**
	18:00	30.3	31.1	33.6	31.4	31.0	30.9	27.9	**30.89^{e} ± 0.142**
Average		**31.5^{b}**	**32.2^{b}**	**34.1^{a}**	**35.3^{a}**	**32.1^{b}**	**32.7^{a}**	**29.0^{c}**	**32.01^{**} ± 0.135**
Winter	06:00	10.3	10.2	14.2	10.7	12.2	9.9	8.7	**11.06^{f} ± 0.135**
	12:00	16.3	21.6	24.3	20.4	22.6	20.5	17.3	**20.89^{d} ± 0.209**
	18:00	13.9	13.9	18.7	14.7	15.1	15.0	11.9	**15.19^{e} ± 0.138**
Average		**13.5^{b}**	**15.2^{b}**	**19.07^{a}**	**15.3^{a}**	**16.6^{a}**	**15.0^{b}**	**12.6^{c}**	**15.71 ± 0.161**

a ,b and c as superscript in the same raw show significant differences between the various skin sites
d, e and f as superscript in the same column show significant differences between time of day for each season ;
**** = P<0.01 between seasons**

Rectal temperatures:

The capacity of the camel to regulate its body temperature in harsh desert environments is phenomenal. Seasonal differences in rectal temperature were only 1.16° C higher in summer than in winter (38.61 *vs* 37.45)°C, respectively (Table 2). Monthly differences within a season were however greater (Mohammed *et al*., 2007 in camels, Robyn *et al*., 2010 in the Oryx and Scharf *et al*., 2010 in cattle). The 06:00 AM rectal temperatures were 37.23°C in summer and 36.77°C in winter, the difference being only 0.46°C. At 12:00 noon, rectal temperature was 40.40°C in summer and 38.30°C in winter, the difference being 2.10°C. Similar results were repeated by Al-Haidary et al. (2005) and Mohammed *et a.l* (2007). In general, seasonal and diurnal variations in rectal temperature followed closely observed changes in the temperature-humidity index (THI) reported in Table 1.

Skin temperature:

McCaffery et al, (1979) and Robertshaw (1985) indicated that the skin of the various parts of the body of cattle varies in its temperature and its ability to exchange heat with the environment. In the present experiment, and in addition to rectal temperature and the measured skin temperature at the stelected sites of the skin surface (Table 3) may enhance our understanding of the camels' heat regulation under desert conditions.

Overall, skin surface temperature were higher in summer as compared to winter ($P<0.01$), 32.01°C *vs* 15.71°C, respectively, and were higher at noon as compared to morning and evening ($P<0.05$). These results are in close agreement with these of Quarterman (1962) in cattle. The hump skin temperature was higher than in other sites probably as it receives more solar radiation. Similar results were reported in cattle and buffaloes (Allan *et al*., 2010). Similar to rectal temperature, skin surface temperature (average of seven sites) was lower than the unshaded ambient temperature both summer and winter and at the different times of the day. Noon temperature gradients were 7.4°C in summer and 6.1°C in winter, the skin surface being cooler than the environment.

Temperature gradients:

The fluctuations of rectal (RT) Skin (ST), coat (MCT) and (CST) and the ambient (Ta) temperatures are illustrated in Tables 4 and 5 and Figure 2. As indicated above, RT was practically constant with some increase at noon and up to 3°C in summer. Early in the morning all skin, mid-coat and coat surface temperatures were in equilibrium with the ambient temperature and irrespective of the large difference in Ta between summer and winter. As the Ta increased at noon, the skin and coat temperatures also increased but were lower than Ta. at 18:00 hr. where the environment started to cool again and Ta decreased, it seems that the equilibrium was nearly restored even though Ta was higher than ST in summer and lower in winter. These changes appear to represent the two phases the camel uses to maintain homeothery. First by allowing its core temperature to rise during the hot day to lessen heat gain from the environment and also to reduce the need for evaporative cooling, thus conserving water. The second is the enhanced passive heat loss during the cooler night.

Temperature gradients from core to ambient were calculated (Table 6). Seasonal effects are evident and in particular the rectal/skin gradient, 6.6 vs. 21.74 °C in summer and winter, respectively. Other gradients were also greater in winter but to a lesser magnitude. Of interest was the observation that in summer the ST was higher than that of the MCT. The opposite was observed in winter, the MCT being higher than the skin. The reverse of that was observed for the MCT/CST gradient. In summer, the CST was higher than the MCT while the MCT was the higher in winter. Pertinent, the CST was less than the Ta in both summer and winter, 6.34 °C and 2.92 °C in summer and winter, respectively.

Table (4): Mean ± SE of diurnal variations in surface coat temperature (SCT, ºC) at different skin sites of the one-humped she camel during summer and winter seasons

Season	Time	Skin Sites							Mean ± SE
		NE	SH	HU	HI	FL	HL	AB	
Summer	06:00	31.5	31.9	33.6	32.6	31.9	32.2	29.9	**31.94^{f} ± 0.095**
	12:00	35.7	36.0	38.8	36.7	36.5	37.3	32.1	**36.16^{d} ± 0.174**
	18:00	31.7	32.8	34	32.8	32.4	32.2	28.9	**32.11^{e} ± 0.134**
Average		**33.0^{b}**	**33.6^{b}**	**35.5^{a}**	**34.0^{a}**	**33.6^{b}**	**33.9^{a}**	**30.3^{c}**	**33.40^{**} ± 0.134**
Winter	06:00	9.1	9.9	11.6	9.4	9.7	9.1	7.4	**9.46^{f} ± 0.105**
	12:00	17.1	18.6	20.3	18.2	18.9	17.9	15.7	**18.10^{d} ± 0.122**
	18:00	11.5	12.4	16.8	13.3	12.9	12.9	9.0	**12.69^{e} ± 0.197**
Average		**12.6^{b}**	**13.6^{b}**	**16.2^{a}**	**13.6^{b}**	**13.8^{b}**	**13.3^{b}**	**10.7^{c}**	**13.41 ± 0.141**

a ,b and c as superscript in the same raw show significant differences among the various skin sites
d, e and f as superscript in the same column show significant differences among time of day for each season ;
**** = P<0.01 between seasons**

Table (5): Mean ± SE of diurnal variations in mid- coat temperature (MCT, ºC) at different skin sites of one-humped she camel during summer and winter seasons

Season	Time	Skin Sites							Mean ± SE
		NE	SH	HU	HI	FL	HL	AB	
Summer	06:00	30.3	30.7	31.3	30.6	30.4	30.7	27.6	**30.23^{e} ± 0.102**
	12:00	33.6	34.2	36.6	34.9	34.7	35.2	30.3	**34.21^{d} ± 0.165**
	18:00	30.0	30.5	31.9	31.1	30.5	30.1	27.8	**30.27^{e} ± 0.107**
Average		**31.3^{b}**	**31.8^{a}**	**33.3^{a}**	**32.2^{a}**	**31.9^{a}**	**32.0^{b}**	**28.6^{c}**	**31.57^{**} ± 0.125**
Winter	06:00	11.1	12.9	15.3	11.6	12.8	11.0	7.9	**11.80^{f} ± 0.192**
	12:00	19.1	22.3	25.6	21.4	23.5	21.3	17.9	**21.58^{d} ± 0.219**
	18:00	15.0	15.8	19.6	16.2	16.3	16.1	13.4	**16.06^{e} ± 0.156**
Average		**15.1^{b}**	**17.0^{b}**	**20.2^{a}**	**16.4^{b}**	**17.5^{a}**	**16.13^{b}**	**13.1^{c}**	**16.48 ± 0.189**

a ,b and c as superscript in the same raw show significant differences among the various skin sites
d, e and f as superscript in the same column show significant differences among time of day for each season ;
**** = P<0.01 between seasons**

Table (6): Temperature gradients from rectal to skin, mid-coat, coat surface and ambient temperatures during summer and winter seasons at different times of the day.

1. Summer:

Time	Rectal/Skin	Skin/Mid-coat	Mid-coat/Surface	Coat surface/Ta
6:00	7.00	0.00	0.71	1.94
12:00	5.47	0.72	1.95	6.34
18:00	7.41	0.62	1.84	2.39
mean	6.60	0.44	1.83	1.73

2. Winter:

Time	Rectal/Skin	Skin/Mid-coat	Mid-coat/Surface	Coat surface/Ta
6:00	25.71	0.74	2.34	0.04
12:00	17.41	1.31	3.48	8.90
18:00	22.11	0.87	3.37	0.19
mean	21.74	0.77	3.07	2.92

Noteworthy, MCT being lower than both skin and Ta helps the dissipation of heat to the environment in the summer, whereas its being higher than skin and Ta in winter lessens heat flow to the environment and helps keep the animal warm. Similar findings were reported by Kawashti *et al*. (1978).

Conclusion:

From the results of the present study it could be concluded that the she camels' coats, which are hairy rather than wooly in nature, create a favorable microclimatic buffer zone that separate the body surface from the surrounding harsh climatic conditions (Gauthier-Pilters and Dagg, 1981). The dense and thick winter coat of camels would enable them to conserve body heat; meanwhile, the light summer coat could minimize the influx of heat from the external environment to the camels' bodies (El-Hassanein, 1989). Meanwhile, it permits the dissipation of metabolic heat and does not interfere with the passage of water vapor from the skin surface to the outer atmosphere (Schmidt-Nielsen 1964, Gauthier-Pilters and Dagg 1981).

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التنظيم الحراري في نوق الجمل وحيدة السنام: التأثير اليومي وفصل السنة على درجة حرارة الجسم وسطح الجلد

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أجريت هذه التجربة فى محطة بحوث مريوط غرب الاسكندرية التابعة لمركز بحوث الصحراء بالقاهرة لتقييم قدرة الجمل وحيد السنام على التكيف الحرارى خلال فصلى الصيف والشتاء. اختيرت خمس نوق يتراوح عمرها بين 4-6 سنوات ووزن مبدئى 552±3.5 و 613± 6.6. كانت الجمال موضوعة فى الخارج فى حظيرة غير مسقوفة و تم قياس درجة حرارة المستقيم و سطح الجلد و سطح الوبر و بين الوبر 3 مرات يوميا (السادسة صباحا والثانية عشرة مساء و السادسة مساء)لمدة عشرة أيام فى منتصف كل شهر من شهور الصيف (من يونيو إلى أغسطس) و من شهور الشتاء (من ديسمبر إلى فبراير). قيست درجة حرارة الجو و الرطوبة النسبية فى الصيف والشتاء فى هذه الاوقات . بالنسبة لتأثير فصل السنة على درجة حرارة المستقيم، أظهرت النتائج وجود اختلافات جوهرية بين فصول السنة. كان متوسط درجة حرارة المستقيم 38.6 و 37.45 فى الصيف والشتاء على الترتيب.

تأثرت درجة حرارة المستقيم أثناء اليوم والموسم بالتغيرات الملحوظة في مؤشر درجة الحرارة والرطوبة. اختلفت درجة حرارة الجلد وكانت التغيرات في الأماكن المختارة أعلى معنويا في الشتاء عن الصيف ، وهذا يعني أن درجة حرارة سطح الجلد تتبع التغيرات المناخية. أظهرت النتائج أيضا فروقا معنوية بين درجة حرارة سطح جلد السنام (المنطقة المعرضة للشمس) وبين درجة حرارة سطح جلد البطن (المنطقة غير المعرضة للشمس)، وكانت درجة حرارة سطح جلد السنام الأعلى خلال فصلي الصيف والشتاء ، وسجلت درجة حرارة سطح الجلد وبين الوبر في البطن أقل الدرجات في فصلي الصيف والشتاء.

وكانت درجة الحرارة بين الوبر أقل من درجة حرارة سطح الوبر فى فصل الصيف و ذلك لتقليل انتقال الحرارة من من الهواء للجلد. و بالعكس كانت درجة حرارة بين الوبر أعلى من سطح الوبر فى الشتاء لتقليل تسرب الحرارة من الجلد للبيئة المحيطة وللحفاظ على درجة حرارة الجلد قدر الممكن مما استدل منه على أن غطاء جسم الجمل يعمل كغرفة تكيفية تحمى سطح الجسم من ارتفاع درجة الحراره فى فصل الصيف (الظروف المناخية القاسية).

قام بتحكيم البحث

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