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REGULAR ARTICLE

Thermophysiological study in lactating and dry camels (*Camelus dromedarius*) under summer conditions

Emad M. Samara*, M. Ayadi, A. A. AL-Haidary and R. S. Aljumaah

Department of Animal Production, College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

Abstract

A comparative study on thermophysiological responses of 24 lactating and non-lactating (dry) camels maintained under natural summer conditions was carried out with 2 Arabian native breeds. Study parameters (meteorology, thermophysiology, infrared thermography) were measured in both breeds at the evening milking (17:00h) throughout 3 consecutive days. It appears evident that lactating camels are more thermally labile than their dry counterparts under such environmental conditions. This fact was proven by higher body temperatures of lactating camels than their dry counterparts (rectal temperature: 38.01 ± 0.07°C VS 37.80 ± 0.06°C and vaginal temperature: 38.20 ± 0.08°C VS 37.79 ± 0.07°C, $P < 0.05$). Additionally, this was further emphasized by the noticeable increases of several thermophysiological parameters in lactating camels including their respiratory rate (6.57%), heart rate (9.36%), as well as body (11.06%), udder (4.74%), teat (5.52%), and milk vein (4.51%) surface temperatures. In conclusion, lactating camels expressed higher thermophysiological responses over dry camels. Infra-red thermography can be a suitable tool for non-invasive method that detects surface heat radiation in dromedary camels.

Key words: Dromedary camel, Infrared thermography, Lactation, Thermoregulation

Introduction

Dairy camels are quite distinct from other dairy animals. This is mainly attributable to their ability to continue lactating even under severe conditions confronted in their natural environmental habitat (Saleh and Faye, 2011; Al-Saiady et al., 2012). Beside the environmental heat load, body heat production and the resultant increase in heat storage associated with lactation in dairy cattle were considered another impingement factors (Shearer and Beede, 1990; Ben Younes et al., 2008). Thus, due to the greater body heat storage, lactating cattle showed higher body temperatures compared to the non-lactating cattle (Araki et al., 1984; El-Nouty et al., 1990). This fact indicates that lactating animals may have greater susceptibility to environmental changes than dry animals. It is definitive, therefore, that lactating animals must dissipate both the heat gained from the environment together with their own metabolic heat to maintain a constant body temperature. In Saudi Arabia, camel population is estimated to be approximately 830,000 heads distributed in different parts of the country (Agriculture Statistical Year Book, 2009). Majahiem (black coat) and Maghatier (white coat) camels are the predominant dairy breeds of camels in Saudi Arabia, where their milk yield under favorable climatic conditions ranged between 6 to 18 liters per day (Aljumaah et al., 2011). Excessive solar heat stress in livestock at the geographical region of Saudi Arabia has been previously recognized (Ali et al., 1999; Al-Haidary, 2006). However, the extent of thermotolerance to such stress by these indigenous dairy camel breeds has not been investigated.

Infra-red thermographic technology (IRT) is a non-contact and non-invasive method that detects surface heat emitted as infrared radiation. This technology has previously been used to study temperature patterns of udder and teat surface temperature in dairy cows (Kunc et al., 2002), dairy ewes (Stelletta et al., 2007), dairy goats (Caruolo et al., 1990), and in lactating camels (Ayadi et al., 2012). Therefore, the IRT technology beside other thermophysiological measurements were adapted to conduct a comparative study between lactating and dry camels belonged to 2 breeds and maintained under the natural summer conditions.

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*Corresponding Author

Emad M. Samara

Department of Animal Production, College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

Email: Dremas@ksu.edu.sa

Materials and Methods

Twenty four dairy dromedary camels of 2 Arabian native breeds (12 Majahiem and 12 Maghatier) were allotted into 2 groups of similar size according to their lactation status (lactating and dry). Dry camels had a mean parity of 2.8 ± 0.1 (means ± SD). Meanwhile, lactating camels (3.1 ± 0.2 parities, 134.2 ± 19.0 days in milk, 9.3 ± 1.1 L/day milk; means ± SD) were regularly milked twice daily (05:00 and 17:00h) using a down pipeline machine milking system (DELAVAL, Riyadh, KSA) at Al-Watania agricultural farm stock intensive industrial system, Al-Jouf, Saudi Arabia. All camels were identified by electronic ear tags (Shearwell Data Ltd, Minehead, Somerset, UK), fed twice a day, and had free access to clean tap water. Daily ration per animal consisted of 13.5 kg of alfalfa hay (DM, 92.2%; CP, 21.8%; NFD, 26.7%; GE, 4.36 Mcal/kg; DM basis) and supplemented with 2 kg of a commercial concentrate (DM, 90.2%; ME, 2.9 Mcal/kg). All camels used in the study were free from clinical mastitis and pregnancy.

Ambient temperature (T_a) and relative humidity (RH) were concurrently and continuously recorded at 15 min interval throughout study period using 2 data loggers (HOBO Pro Series data logger, Model H08-032-08, ONSET Co., Wareham, MA, USA) mounted in the barn at a height of approximately 2 m from the ground, and placed away from direct sources of heat, sunlight and water. Special data logging software (BoxCar Pro 4, ONSET Co., Wareham, MA, USA) was applied for programming the loggers and for data analysis.

Before the evening milking (17:00h), a variety of thermophysiological measurements were quantified for each lactating and dry camel throughout 3 consecutive days. Rectal (T_r) and vaginal (T_v) temperatures in addition to respiratory (RR) and heart (HR) rates were determined. Measurements were recorded using a digital thermometer (ARTSANA digital thermometer, Grandate Co, Italy) measure to the nearest 0.1ºC for T_r and T_v. Meanwhile, camels' RR and HR were recorded by placing the diaphragm of the stethoscope (3M Littmann Classic II S.E. Stethoscope, UK) in the space between the 9th and 11th ribs or between the 3rd and 6th intercostals spaces, counting 10 breath/beat, and then expressing the recorded time as number of breathes/beats per minute, respectively.

For dry surfaces, body, udder, teat and milk vein surface temperatures (Ts) were recorded simultaneously with thermophysiological measurements. Left side thermograms (infrared thermographic images) for body, udder, teat (front and rear) as well as milk vein surfaces were obtained using a forward-looking and automatically calibrating infrared camera (VisIR-Ti200 infrared vision camera, Thermoteknix Systems ltd, Cambridge, UK) placed perpendicular and approximately 150 cm (for body thermograms) or 50 cm (for udder, teat and milk vein thermograms) away from camel's surfaces. This camera was equipped with 25° lens, 1.3 M pixel visible camera, and LCD touch screen. The spectral range and precision of the camera were 7.5–13 μm and ± 0.1°C, respectively.

After capturing, thermograms were stored inside a 250 MB internal memory, readout and analyzed using a special thermograms analysis program (TherMonitor, Thermoteknix Systems ltd, Cambridge, UK). For all thermograms, the rainbow color scheme was chosen. A total of 143 thermograms were analyzed by defining areas circumscribed by hand with the software functions. The software then calculated the average, minimum, and maximum T_s within the defined areas. Additionally, the distance between the camels and the camera as well as emissivity of animal body was supplied for the camera to compensate for the effects of different radiation sources. It's worth mentioning that the recording time between camels was kept to minimum, and similar body emissivity (0.97; Monteith and Unsworth, 1990) was used for all thermograms. Illustrations of body, udder, teat and milk vein thermograms of lactating and dry dairy camel obtained under the same T_a and within the same barn are presented in Figure 1.

Study data were analyzed using the random model of the general linear model procedure of the statistical analysis system (Statistical analysis systems, 2003). To determine the differences between lactating and dry camels; the influence of animal, breed (Majaheim and Magateir), lactation status (lactating and dry) and their respective interactions were included in the model. Statistically significant differences between means were determined by Fischer's least significant difference. The overall level for statistical significance was set at $P < 0.05$.

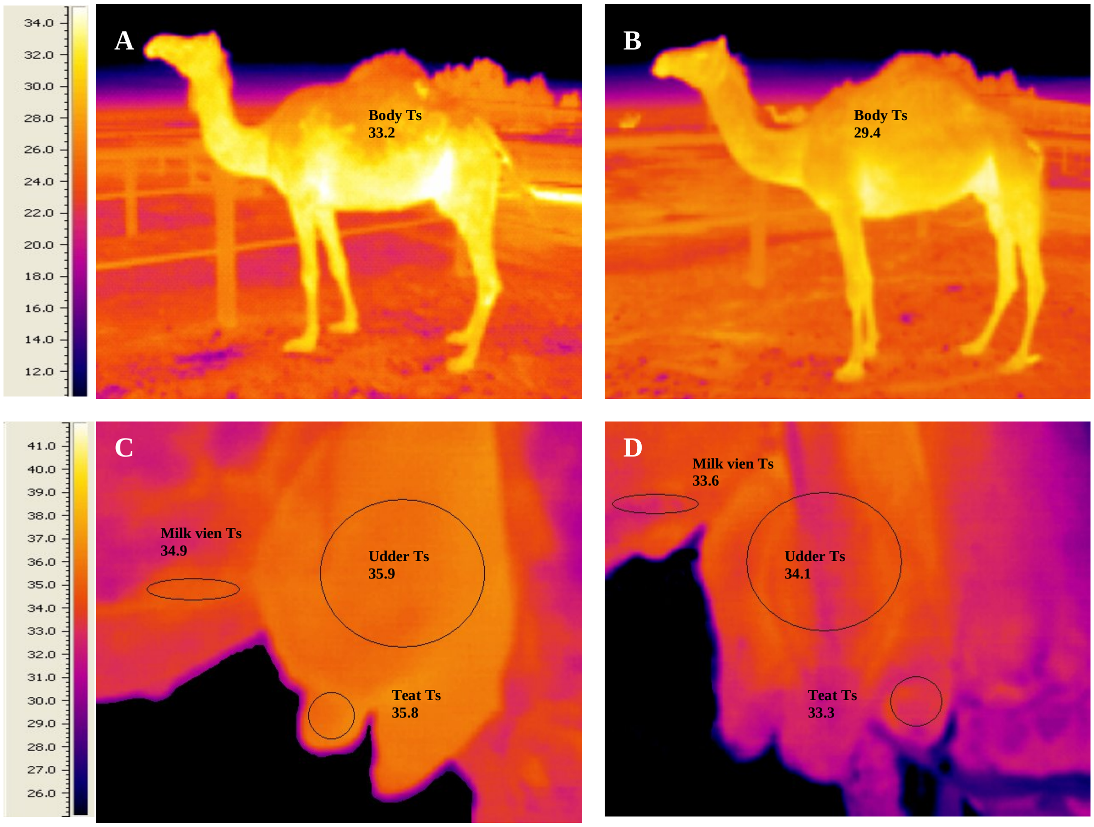

Figure 1. Body and udder thermograms of lactating (A and C) and dry (B and D) dairy camels obtained under the same ambient temperature (*Ta* = 34.93 °C) and within the same barn. In these thermograms, mean body and udder surface temperatures are clearly higher in lactating camel than dry counterpart.

Results

Meteorological measurements

Overall means of daily recorded barn T_a and RH were 37.7 ± 0.4°C and 15.2 ± 0.9%, (means ± SD) respectively. Moreover, recorded T_a showed a circadian rhythm, with minimum values (20-21°C) were recorded at early morning (05:00-06:00 h) and maximum values (40-41°C) at middle of the day (14:00 - 15:00 h). Meanwhile, overall mean of RH showed the reverse trend, where relative humidity of 34% and 10% were associated with minimum and maximum T_a, respectively.

Thermophysiological and IRT measurements

In the current study, no differences ($P>0.05$) in the measured thermophysiological and IRT measurements were observed between both camels breeds. Alternatively, these measurements were influenced by animal's lactation status where lactating camels had higher values than their dry counterparts (Table 1). The overall means of thermophysiological measurements (T_r, T_v, RR, and HR) revealed higher values in lactating camels compared to dry camels ($P<0.05$) (Table 1). Furthermore, overall means of different body parts T_s measured by IRT showed higher values in lactating camels compared to their dry counterparts ($P<0.05$) (Table 1).

Table 1. Least squares means of thermophysiological and infrared thermographic measurements of lactating and dry camels belonging to 2 breeds (n= 24).

Parameters	Lactation Status		Difference %
	Lactating (n= 12)	Dry (n= 12)	
Thermophysiology			
T_r (°C)	38.01 ± 0.07 [a]	37.80 ± 0.06 [b]	0.53
T_v (°C)	38.02 ± 0.08 [a]	37.79 ± 0.07 [b]	0.58
RR (breath/min)	15.82 ± 0.28 [a]	14.78 ± 0.24 [b]	6.57
HR (beat/min)	55.01 ± 1.81 [a]	49.86 ± 1.73 [b]	9.36
Infrared thermography			
Body T_s (°C)	33.12 ± 0.21 [a]	29.46 ± 0.20 [b]	11.06
Udder T_s (°C)	36.07 ± 0.15 [a]	34.36 ± 0.14 [b]	4.74
Teats T_s (°C)	35.51 ± 0.11 [a]	33.55 ± 0.11 [b]	5.52
Milk vein T_s (°C)	35.33 ± 0.19 [a]	33.74 ± 0.18 [b]	4.51

a-b Mean values within the same row bearing different superscripts are significantly different at $P<0.05$.

Tr: rectal temperature, *Tv*: vaginal temperature, *Ts*: surface temperature, RR: respiratory rate, and HR; heart rate.

Discussion

Homeothermic body can be described as an open thermodynamic system; that continuously exchanges heat with its external environment using several thermoregulatory mechanisms (Al-Haidary, 2000). Under heat stress conditions, physiological thermolytic responses are dominated to assist for more body heat dissipation. They incorporate an external shift of blood distribution (increase in peripheral to splanchnic blood flow ratio) (da Silva and Maia, 2011; Abdoun et al., 2012), inhibition of thermogenic hormone production (Al-Haidary et al., 2001, 2002), and recruitment of evaporative mechanisms (de Lamo et al., 2001; Scharf et al., 2008; Abdoun et al., 2012). Most mammals employ panting and/or sweating for evaporative heat dissipation (Willmer et al., 2000). Dromedary camel, in particular, is mainly a sweating animal with respiratory water loss of only 3% of the total evaporative water loss (Schroter et al., 1987; de Lamo et al., 2001).

When lactating camels were compared to their dry counterparts in the current study under the natural summer conditions, lactating camels exhibited higher body temperatures (T_r and T_v). These differences were expected due to greater body heat storage of the lactating camels. Thermal homeokinesis is a steady state where body temperature is relatively maintained constant despite any fluctuating of the external environment (International union of physiological sciences, 2001). According to this definition, it appears that lactating camels are more thermally labile than dry camels. This finding is consistent with the previous studies on dairy cattle which reported that body temperatures of early and/or late lactating dairy cattle are higher than dry cattle (Araki et al., 1984; El-Nouty et al., 1990; Vickers et al., 2010).

The higher body temperatures of lactating camels reinforce the basic axis that lactating animals have greater susceptibility to environmental changes than dry animals. It is definitive, therefore, that lactating camels must dissipate both the heat that gained from the environment together with its own metabolic heat to maintain a constant body temperature. In response to the increased thermal load, noticeable divergences in several thermophysiological measurements including the RR, HR, as well as all T_s parameters were occurred in lactating camels compared to their dry counterparts. The slight tachypnea (approximately 7%) in RR of lactating 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). The possibility of consuming more drinking water by lactating camels than their dry twins to compensate for the potential rise in evaporative water loss is of further interest. Moreover, particular attention should be given to the significant differences (approximately 10%) in HR between lactating and dry camels. This manifests a clear evident that an extensive change in hemodynamics was initiated in lactating camels over their dry counterparts (Table 1). This response is mainly attributed to the increased cutaneous blood flow due to blood redistribution from deep splanchnic to peripheral body regions (Abdoun et al., 2012). This fact was actually observed using IRT, where body, udder, teat and milk vein T_s of lactating camels exhibited noticeable percentage alterations (5-11%; Table 1) over the dry dairy camels.

In case of lactating animals, however, milking can be a special heat dissipation avenue (Araki et al., 1984). Because more than 85% of most mammals' milk is water (Mepham, 1987), milk would possess a high heat capacity and therefore a considerable part of body heat can be stored in the milk. Consequently, milk removal from the animals may reduce the amount of heat that must be dissipated to lower body temperature. This fact was actually observed in dairy cattle maintained under heat stressed conditions. Araki et al. (1984) reported a decrease in the body temperatures of dairy cattle immediately to several hours after milking when animals were sent back to their pens. Additionally, Ben Younes et al. (2008) demonstrated that milking had resulted in a decrease in udder as well as body (rectal and vaginal) temperatures of dairy cattle. These observation emphasize that milking can alleviate the environmental heat stress in dairy cattle. Numerous studies have monitored the circadian rhythm of body temperature in lactating and dry dairy cattle in their natural habitat (Araki et al., 1984; Al-Haidary, 2000; Vickers et al., 2010). Unfortunately, however, the circadian rhythm of body temperature in dairy camels has not been defined. Thus, it seems very demanding to characterize the circadian rhythm of core body temperature for dry, early, and late lactating camels with the advance of telemetry equipments nowadays to accurately measure the difference between lactating and dry camels.

Conclusions and recommendations

Current study sheds, for the first time, some basic light upon the thermophysiological responses of lactating and dry camels. It appears evident that lactating camels are more thermally labile than dry camels, as emphasized by the noticeable increases of several thermophysiological and infrared thermographic parameters in lactating camels over their dry counterparts. Management can significantly alter body temperatures of lactating camels. Offering shade as well as cooling during the hottest time of the day can affect favorably body heat storage in subsequent periods by rectifying heat stress conditions. This may improve milk production and reproductive performance of dairy camels. The economic importance of such possibility can have far reaching consequences.

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