Effect of summer climatic conditions on different heat tolerance indicators in primiparous Friesian and Jersey cows

C.J.C. Muller* and J.A. Botha
Elsenburg Agricultural Development Institute, Private Bag, Elsenburg, 7607 Republic of South Africa

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The effect of climatic conditions during summer on different heat tolerance indicators was determined in Friesian and Jersey cows which were kept in open camps with no protection against solar radiation. A complete diet (15.0% CP and 10.8 MJ ME/kg) was fed daily on an *ad libitum* basis in fence-line feeding troughs. Heart rates, respiration rates and rectal temperatures of five primiparous Friesian and five primiparous Jersey cows, which were accustomed to handling, were measured at two-hourly intervals from 07:00 to 19:00 over 15 days during which high (≥27.1 °C) maximum temperatures were expected. Rectal temperatures of Friesian cows were higher ($P \leqslant 0.05$) than those of the Jersey cows from 11:00 to 19:00, with the greatest difference (0.55 °C) recorded at 15:00. The respiration rate of Friesian cows was higher ($P \leqslant 0.05$) than that of Jersey cows at 15:00, 17:00 and 19:00, with the greatest difference (15.4 inhalations per minute) recorded at 15:00. The heart rate of the Friesian group was higher ($P \leqslant 0.05$) than that of the Jersey cows at 15:00 and 17:00. Heart rate was not influenced by increasing ambient temperatures to the same extent as rectal temperature and respiration rate. Results suggest that Jersey cows display a higher heat tolerance than Friesian cows, and that Jerseys should be more widely used in the warmer regions of South Africa.

Die invloed van klimaattoestande gedurende die somer op verskillende warmteverdraagsaamheidsaanwysers is by Fries- en Jerseykoeie wat in oop kampe sonder enige beskutting teen sonstraling aangehou is, bepaal. 'n Volledige dieet (15.0% RP en 10.8 MJ ME/kg) is daagliks op 'n *ad libitum*-basis aan koeie in voerkrippe langs die grensdraad voorsien. Die rektale temperatuur, asemhalingstempo en hartklop van vyf eerste-laktasie Fries- en vyf eerste-laktasie Jerseykoeie wat aan hantering gewoond was, is oor 'n tydperk van 15 dae met verwagte hoë maksimum temperature (≥27.1 °C), elke twee ure vanaf 07:00 tot 19:00 bepaal. Die rektale temperatuur van Frieskoeie was vanaf 11:00 tot 19:00 hoër ($P \leqslant 0.05$) as by Jerseykoeie. Die grootste verskil (0.55 °C) tussen die twee rasse het om 15:00 voorgekom. Die asemhalingstempo van Frieskoeie was om 15:00, 17:00 en 19:00 hoër ($P \leqslant 0.05$) as by Jerseykoeie. Die grootste verskil (15.4 asemhalings per minuut) het om 15:00 voorgekom. Die hartklop van Frieskoeie was eweneens om 17:00 en 19:00 hoër ($P \leqslant 0.05$) as dié van Jerseykoeie. Die hartklop van beide rasse is nie tot dieselfde mate as rektale temperatuur en asemhalingstempo deur toenemende omgewingstemperature beïnvloed nie. Resultate bevestig die hoër hitteverdraagsaamheid van Jerseykoeie wat daarop dui dat hierdie ras meer in die warmer dele van Suid-Afrika gebruik kan word.

Keywords: Friesian and Jersey cows, heart rate, heat, Mediterranean climate, rectal temperatures, respiration rate.

* To whom correspondence should be addressed.

Introduction

It is well-known that heat stress reduces feed intake, milk production and reproduction rate. Increased rectal temperatures (an indication of body core temperature) as well as respiration and heart rates are usually indications of heat stress (Thompson, 1973; Singh, 1980; Barth, 1982; Shafie, 1989). Heat stress is due mainly to high environmental temperatures, relative humidity and solar radiation. Of these factors, air temperature is the single most important bioclimatic factor that influences production (McDowell, 1972). Breeds differ in their physiological response and adaptation to thermal environments (Young, 1985). It has been assumed that some physiological responses, such as body temperature and respiration rate, indicate the degree of efficiency of the thermoregulatory processes of the body (Harris *et al.*, 1960). Kamal & Ibrahim (1969) showed that, during summer in Egypt, Friesian cows displayed higher respiration and heart rates as well as rectal temperatures than did indigenous Water Buffaloes. According to McDowell *et al.* (1953), crossbred Sindhi-Jersey (F_1) cows showed a smaller increase in rectal temperature than did pure Jersey cows under similar climatic conditions. The respiration rate of crossbred cows was slightly higher than that of Jersey cows (144.6 vs. 141.6). Singh & Bhattacharyya (1990) compared the cardio-respiratory activity of Harianna cattle (*Bos indicus*) and their F_1 crosses with that of Jersey, Brown Swiss and Holstein–Friesian cows at different ambient temperatures inside a climatic chamber. Differences in pulse rate, respiration frequency and ventilation rate were significant between the genetic groups. Harris *et al.* (1960) showed differences between Friesian and Jersey cows in body (rectal) temperature ($P \leqslant 0.01$), respiration rates ($P \leqslant 0.05$) and pulse rates ($P \leqslant 0.05$) in central Texas, USA. It is therefore generally accepted that Jersey cows are more resistant to high ambient temperatures than Friesian cows (Harris *et al.*, 1960; West *et al.*, 1990; Legates *et al.*, 1991), although little is known concerning the comparative performance of these two breeds in South Africa.

In the Western Cape, Friesian and Jersey cows are the most popular milk-producing breeds. This is shown in three subregions of the Winter Rainfall Region, namely the Swartland, Boland and South Coast, where these breeds constitute 90 and 6%; 63 and 29%; and 24 and 46%, respectively of all cows (Baard, 1989). In these regions, cows are kept mainly in open camps (dry lots) where feed is provided on a daily basis, or on pasture with usually little or no protection against adverse climatic conditions. The climate is typically Mediterranean, with long, hot, dry summers and rain falling predominantly during the winter (May to August). Summer days are characterized by periods of intense heat which vary in duration, while the nights are relatively cool (Myburgh, J., 1990, personal communication, SIRI, Elsenburg). Considering the optimum ambient temperature range of 13 to 18 °C (McDowell, 1972), it is clear that dairy cows are normally well adapted to relatively cool conditions, but are sensitive to high ambient temperatures during summer. The most serious problem in most parts of the world is not to keep adult farm animals warm during the winter, but to keep them cool in summer (McDowell, 1972).

In the Winter Rainfall Region there is a gradual trend towards intensive housing for dairy cattle. There is, however, no information concerning the effect of natural summer conditions (in the open with no protection against high ambient temperatures) on the milk production, feed efficiency and reproduction parameters of dairy cows in this area. Indicators of heat tolerance may be useful to estimate the level of possible heat stress on dairy cows. Housing conditions that cause similar effects on these indicators may point to incorrect housing design for a specific area.

The objective of this study was to measure the effects of high ambient temperatures on heart rate, respiration rate and rectal temperature of primiparous Friesian and Jersey cows at different times of the day during summer in a temperate region. As night temperatures in the Western Cape are usually under 24 °C (minimum ambient temperature *ca.* 15 °C), it was not necessary to extend these measurements over a 24-h period. A complete description of the effect of heat stress on production parameters of the two breeds will be presented in a later paper.

Materials and Methods

Five primiparous Friesian and five primiparous Jersey cows (492 ± 39 and 339 ± 28 kg live mass and milk production of 23.8 ± 2.8 and 18.3 ± 2.0 kg/d, respectively) from the Elsenburg herds, which were accustomed to handling, were used in the experiment. Cows were selected to form groups as similar as possible in terms of age (2.5 ± 0.3 and 2.4 ± 0.1 years) and stage of lactation (112 ± 59 and 93 ± 23 days in milk). Experimental cows were kept with other cows in open camps adjacent to each other, providing approximately 100 m^2/cow without any protection against direct solar radiation. Cows were machine-milked twice daily at 05:00 and 15:30. For each milking, cows were moved as separate groups to the milking parlour approximately 150 m from the open camps, and were brought back immediately after milking. A complete diet consisting of 40% coarsely-milled oat hay and 60% concentrates, providing 15.0% CP and 10.8 MJ ME/kg, was fed *ad libitum* daily to cows in fence-line feeding troughs. Fresh feed was provided while the cows were in the milking parlour. Drinking water was provided *ad libitum* in separate troughs in each camp. Ambient temperatures (maximum and minimum) and relative humidity levels were measured hourly with a standard thermohydrograph inside a Stevenson screen at a weather station located approximately 1 km from the experimental site.

The heart rate, respiration rate and rectal temperature of the cows were recorded at two-hourly intervals from 07:00 to 19:00 on 15 days during January and February 1989, when the maximum ambient temperatures were expected to be high ($\geq$27.1 °C). Heart rates were obtained by palpating the pulse at the middle and ventro-lateral coccygeal arteries of the tail for a period of 60 s. Respiration rates were measured by visually observing and counting flank movements of cows over a 1-min period of uninterrupted breathing. Rectal temperatures were obtained by inserting a veterinary thermometer approximately 80 mm into the rectum for a period of 60 s and recording readings to two decimal points. A halter was put on all cows one week prior to the first observation to accustom cows to being restrained. Care was taken to ensure that animals were not unduly disturbed before being restrained for parameter measurements.

The main objective of this study was to determine the effect of diurnal variation in ambient temperature on some physiological parameters associated with heat stress in dairy cows. For this purpose, a simple statistical procedure was followed. Data for both breeds were averaged within times of the day across days and compared by pairwise *t*-test procedures. Polynomial regressions were also fitted (up to degree 3) for the various parameters and breeds against ambient temperature, as well as time of day as independent variables (Snedecor & Cochran, 1980).

Results and Discussion

Ambient conditions on the 15 test days were typical for this area in the Western Cape during summer. Maximum and minimum ambient temperatures were 31.7 ± 3.6 and 15.2 ± 3.7 °C, respectively. Relative humidity levels were inversely related ($P \leq 0.01$) to maximum temperature. Minimum relative humidity levels of 25.8 ± 5.2% were recorded daily between 13:00 and 15:00. Temperature-humidity index (THI) values for test days, based on maximum temperature and minimum relative humidity levels, were 76.3 ± 4.0, which indicate a level above the critical THI for milk production (72—78.0) (Du Preez *et al.*, 1990). As a cool night helps animals to restore thermal equilibrium after being subjected to high day-time temperatures, the number of stress hours per day (ambient temperature exceeding upper critical temperatures), expressed as a percentage of a 24-h period, would be a more precise estimate of the duration of heat stress (McDowell, 1972). According to hourly ambient temperatures, cows were within their comfort range (below an ambient temperature of 21 °C for Friesian cows and 24 °C for Jersey cows; Johnson, 1985) for 10.5 ± 3.7 and 13.7 ± 3 h/d for Friesian and Jersey cows, respectively.

Comparative rectal temperatures, respiration rates and heart rates for Friesian and Jersey cows are presented in Table 1. The change in indicators was generally the same for both breeds, although parameters measured were higher for the Friesian group at different times of the day. Rectal temperatures at 07:00, when ambient temperatures were on average 16.5 °C, were found to be 38.3 and 38.2 °C for Friesian and

Table 1 Comparative performance (mean ± standard deviation) of primiparous Friesian and Jersey cows in terms of rectal temperature, respiration rate and heart rate at different times of the day

Parameter	Hour	Friesian	Jersey	Difference (Fr – Je)
Rectal temp. (°C)	07:00	38.29 ± 0.21^{a}	38.22 ± 0.19^{a}	0.07
	09:00	38.36 ± 0.19^{b}	38.33 ± 0.15^{b}	0.03
	11:00	38.54 ± 0.26^{abc}	38.39 ± 0.31^{c}	0.15*
	13:00	38.99 ± 0.43^{abc}	38.57 ± 0.20^{abcd}	0.42*
	15:00	39.05 ± 0.52^{abc}	38.50 ± 0.18^{abce}	0.55*
	17:00	39.00 ± 0.40^{abc}	38.73 ± 0.12^{abcde}	0.27*
	19:00	39.02 ± 0.36^{abc}	38.69 ± 0.18^{abce}	0.33*
Respiration rate	07:00	43.8 ± 6.3^{a}	37.5 ± 7.7^{a}	6.3
	09:00	58.1 ± 12.7^{b}	60.4 ± 11.0^{ab}	–2.3
	11:00	76.0 ± 20.2^{ac}	73.7 ± 14.5^{ac}	2.3
	13:00	87.0 ± 22.3^{abd}	80.6 ± 17.9^{abd}	6.4
	15:00	79.1 ± 24.7^{abe}	63.7 ± 17.4^{ade}	15.4*
	17:00	62.4 ± 16.8^{d}	52.5 ± 11.8^{acd}	9.9*
	19:00	51.4 ± 13.6^{cde}	41.8 ± 7.9^{bcde}	9.6*
Heart rate	07:00	78.5 ± 5.2^{a}	77.7 ± 3.6^{a}	0.8
	09:00	82.1 ± 4.1	83.2 ± 4.3^{ab}	–1.1
	11:00	84.1 ± 4.3^{a}	82.9 ± 3.5^{ac}	1.2
	13:00	82.0 ± 3.5	80.7 ± 3.1	1.3
	15:00	81.4 ± 3.1	78.2 ± 2.9^{bcd}	3.2*
	17:00	81.9 ± 4.1	78.6 ± 4.7^{bc}	3.3*
	19:00	83.2 ± 4.6	82.3 ± 3.3^{ad}	0.9

$^{a–e}$ Values in columns with the same superscripts differ significantly ($P \leq 0.05$).

* Differences are significant at $P \leq 0.05$.

Jersey cows, respectively. The normal body temperature of Holstein–Friesian and Jersey cows in thermoneutral conditions is 38.3 °C (West *et al.*, 1990) and 38.2 °C (McArthur, 1982), respectively. Rectal temperatures of the cows increased when ambient temperatures exceeded *ca.* 23 °C. The best equations (highest R^2) were: $y = 36.68 + 0.268x - 0.00758x^2$; $R^2 = 0.723$ for Friesian cows, and $y = 37.93 + 0.042x$; $R^2 = 0.703$ for Jersey cows. Rectal temperatures of Friesian cows increased significantly ($P \leq 0.05$) when ambient temperatures reached 28.0 °C (at 11:00). Rectal temperatures of Jersey cows were not affected ($P > 0.05$) by the same temperature change. Rectal temperatures of Friesian cows at all hours from 13:00 to 19:00 were higher ($P \leq 0.05$) than rectal temperatures at 11:00. In contrast, Jersey cows showed significant differences ($P \leq 0.05$) in rectal temperature between 13:00 and 17:00 as well as between 15:00, 17:00 and 19:00. These results agree with those of Roman-Ponce *et al.* (1977), who examined the responses of Holstein and Jersey cows to a shade structure in Florida, USA. In that study, cows out of the shade exhibited peaks in rectal temperature around midday, whereas cows in the shade peaked during late afternoon. According to Prosser (1969), at any given time, body temperature of an animal depends not only on the heat load at that time, but also on the preceding heat load. Berman & Meltzer (1973) have found a large time lag (3 h) between peak black globe temperatures and rectal temperatures in lactating Friesian cows in Israel, where rectal temperature also increased sharply from 09:00 to 15:00.

The relationship between ambient temperatures and rectal temperatures of Friesian and Jersey cows is presented in Figure 1. The correlation between the two variables was 0.79 ($P \leq 0.01$) for Friesian cows and 0.55 ($P \leq 0.05$) for Jersey cows. Chaudry *et al.* (1990) found significant correlations of between 0.28 to 0.45 for F_1 Holstein × Sahiwal, F_1 Jersey × Sahiwal and Sahiwal cows under subtropical conditions.

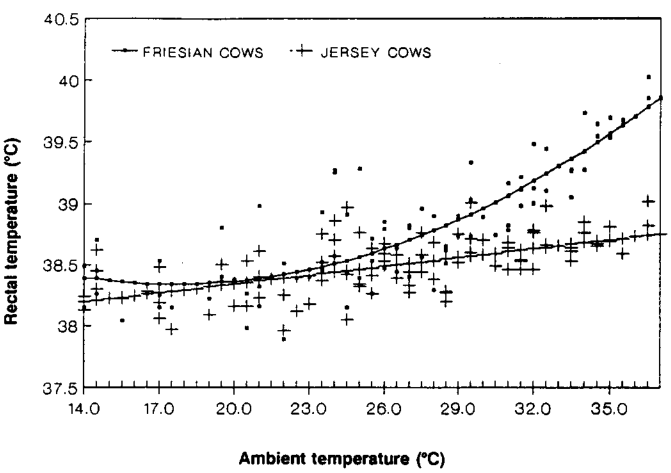

Figure 1 The relationship between ambient temperature (x) and rectal temperature (y) of Friesian [$y = 39.57 - 0.1403(SE = 0.0354)x + 0.004(SE = 0.0007)x^2$; $R^2 = 0.63$] and Jersey cows [$y = 37.86 - 0.02405(SE = 0.0036)x$; $R^2 = 0.30$].

Turner *et al.* (1989) found a correlation of 0.54 between the rectal temperature of Holstein cows and a THI, which suggests that rectal temperature is related to ambient conditions such as ambient temperature, relative humidity and solar radiation. The variation in rectal temperature owing to a variation in ambient temperature was 63 and 30% for Friesian and Jersey cows, respectively, which seems to indicate that Friesian cows were more influenced by ambient temperature than were Jersey cows. Similarly, Kamal & Ibrahim (1969) found that the rectal temperatures of Friesian cows and Water Buffaloes increased from spring to summer ($P \leq 0.01$), with corresponding increases in daytime heat loads, ranging between 0.1 to 0.6°C in Friesian cows and 0.1 to 0.4°C in Water Buffaloes. In the present study, rectal temperatures differed significantly ($P \leq 0.05$) between breeds at all hours from 11:00 to 19:00, with the greatest difference (0.55°C) occurring at 15:00.

The respiration rate of Friesian and Jersey cows increased quadratically ($y = -95.95 + 26.68x - 1.003x^2$; $R^2 = 0.79$ and $y = -92.39 + 25.94x - 1.007x^2$; $R^2 = 0.62$, respectively) during the day. Respiration rate reached a peak in both breeds at 13:00. The difference of 6.4 inhalations/min between breeds was not significant ($P > 0.05$). The respiration rate of Friesian cows was higher ($P \leq 0.05$) than that of Jersey cows at 15:00, 17:00 and 19:00. The biggest difference ($P \leq 0.05$) of 15.4 inhalations/min occurred at 15:00. These results agree with those of Roman-Ponce *et al.* (1977), who found peak respiration rates of 75 and 115 inhalations/min for cows in and out of shade at 12:00. The average respiration rate during the day for Friesian and Jersey cows was 65.4 ± 16.1 and 58.6 ± 18.0 inhalations/min, respectively. Chaudry *et al.* (1990) found that the respiration rate of F_1 Holstein × Sahiwal, F_1 Jersey × Sahiwal and Sahiwal cattle was 64.9 ± 10.0, 55.6 ± 9.9 and 35.1 ± 6.4 inhalations/min, respectively, during summer in the Punjab. According to McDowell *et al.* (1953) and Legates *et al.* (1991), cattle usually show an increased respiratory activity under hot conditions (owing to solar radiation), in order to reduce body temperature. The increase in respiration rate may be attributed directly to increasing ambient temperatures (Figure 2). The response to increasing ambient temperatures was the same for both breeds ($P \leq 0.01$). The respiration rate of Friesian cows was influenced to a greater extent ($R^2 = 0.71$ vs. $R^2 = 0.56$) than was that of Jersey cows. The significance of the increase in respiration rate owing to heat is that it enables the animal to dissipate about 30% of its heat by respiratory vaporization (McLean, 1963). Excessive respiratory activity, however, increases heat production and may also lead to a respiratory alkalosis (Bianca & Findlay, 1962). It is generally thought that animals showing a higher respiratory activity under hot conditions would have an advantage over those with a lower activity (McDowell *et al.*, 1953). Various studies in fact showed the opposite effect, because a rise in respiration rate is usually accompanied by a fall in tidal volume (McDowell *et al.*, 1953; Findlay & Whittow, 1966). McDowell *et al.* (1953) considered respiration frequency a less meaningful and dependable heat tolerance index than measurement of tidal volume, although respiration rate is most easily observed in the field.

Heart rate was not influenced to the same extent as rectal temperature and respiration rate. Lemerle & Goddard (1986) also suggested that respiration rate and rectal temperature appeared to be more sensitive indicators of heat stress than heart rate. Maximum heart rates were recorded at 11:00 for Friesian cows and at 09:00 for Jersey cows. Cubic regression equations of heart rate on hours of the day were determined for both breeds ($y = 23.91 + 14.045x - 1.076x^2 + 0.0264x^3$; $R^2 = 0.28$ for Friesian and $y = -10.37 + 23.504x - 1.894x^2 + 0.048x^3$; $R^2 = 0.53$ for Jersey cows). Singh & Bhattacharyya (1990) found that pulse rate was quite variable at different test temperatures in different genetic groups. There was an initial increase in pulse rate at 27°C and a tendency to fall at 32°C. Ambient temperatures in the present study increased from 23.0 to 28.0°C from 09:00 to 11:00, corresponding to an increase in heart rate. However, heart rate declined at 15:00 when the ambient temperature was 30.7°C. According to Singh & Bhattacharyya (1990), this may be due to peripheral vasodilation which helps to increase heat loss within the zone of thermoneutrality. European cattle, subjected to chronic, moderate heat showed a decreased pulse rate (Kibler & Brody, 1951), whereas those subjected to severe heat showed an

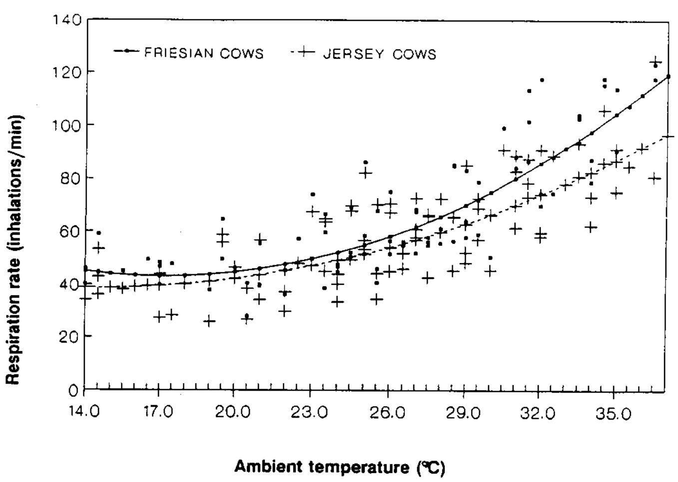

Figure 2 The relationship between ambient temperature (x) and respiration rate (y) of Friesian [$y = 101.1 - 6.728(SE = 1.511)x + 0.195(SE = 0.030)x^2$; $R^2 = 0.708$] and Jersey cows [$y = 62.80 - 3.315(SE = 1.614)x + 0.115(SE = 0.032)x^2$; $R^2 = 0.556$].

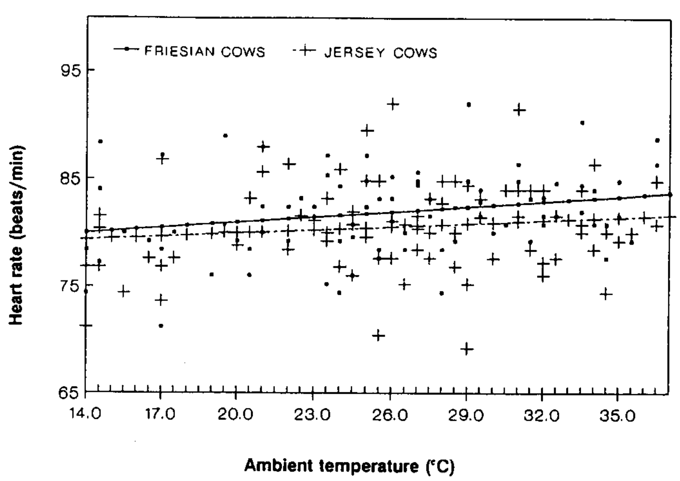

Figure 3 The relationship between ambient temperature (x) and heart rate (y) of Friesian [$y = 76.82 + 0.19(SE = 0.072)x$; $R^2 = 0.065$] and Jersey cows [$y = 77.84 + 0.10(SE = 0.071)x$; $R^2 = 0.019$].

increased pulse rate (Whittow, 1971). The relationship between ambient temperature and heart rate of Friesian and Jersey cows is presented in Figure 3. From this it seems that only 6.5 and 1.9% of the variation in heart rate for Friesian and Jersey cows was accounted for by a variation in ambient temperature.

Factors influencing differences in response to heat stress between breeds may be related to coat colour, and type, thickness of fatty layers under the skin and milk production levels. It has been shown by Hansen (1990) that coat colour influences the effect of heat stress on Holstein cows. Predominantly black cows had higher rectal temperatures, respiration rates and showed more often open-mouthed breathing than mainly white cows in an unshaded environment. According to McDowell (1972), white or light-coloured hair affords some advantage in reflecting thermal radiation, thus reducing the uptake of heat by the body. Jersey cows generally have a lighter hair colour than Friesian cows. Ragsdale *et al.* (1957), as cited by McDowell (1972), have found that the hair coat of cattle in their climate-controlled laboratories (room temperature 27 °C) tended to get lighter over a 12-month period. Cattle have a sweat gland at the base of each hair follicle, thus the number of follicles per unit area will have an influence on the potential effectiveness of heat loss by sweating (McDowell, 1972). There is, however, little difference between follicle density (600—1 100 vs. 550—1 095) between Jersey and Friesian cattle in the USA (McDowell, 1972). Morphological studies (Barker & Nay, 1964) showed that Jersey cows have small, baggy sweat glands, resulting in a skin structure which is characteristic of some *Bos indicus* breeds. According to these authors, this supports the hypothesis that the Jersey breed may have included Zebu-type cattle among its ancestors (Boston, 1954). The resistance of Zebu cattle to heat is due, in part, to a 20% lower metabolic rate than European temperate breeds such as the Friesian (Shafie, 1989). Cattle indigenous to warm climates tend to have shorter hair coats, because length of hair is inversely related to rate of surface evaporation (Bonsma *et al.*, 1953; McDowell, 1972). Jersey cows seem to have shorter hair than Friesian cows. Yeates (1965), as cited by McDowell (1972), reported increased heat tolerance to heat stress after clipping the hair coat short. When fat is stored beneath the skin, heat loss is impaired (McDowell, 1972). Friesian cows generally have more fat deposited beneath the skin than Jersey cows. It is generally accepted that cows with higher milk productions have higher levels of metabolic heat production, thereby increasing the heat load (Beede & Collier, 1986; West *et al.*, 1990). Metabolic heat loads account for 40 to 50% of total heat load requiring heat dissipation (Finch, 1976). The higher milk production of Friesian cattle together with other factors, may result in these cows showing a more pronounced effect of heat stress than do Jersey cattle.

Conclusions

Distinctive breed differences in rectal temperature, respiration rate and heart rate were shown in this field study. Jersey cows displayed lower values for heat-stress indicators on hot days (maximum ambient temperature $\geqslant$27.1 °C), suggesting higher heat tolerance capabilities. This may be due mainly to their smaller body size in comparison to Friesian cows and therefore a correspondingly greater surface area/body weight ratio. A higher level of production and related physiological factors also increased heat load in Friesian cows. Other factors influencing differences between breeds are hair colour and length (lighter and shorter in Jersey cows), thickness of skin (thinner in Jerseys), and fat deposits under the skin (less in Jerseys). It has generally been accepted that animals showing a smaller rise in body temperature are considered more fit for living in a hot environment than ones that show a major shift in body temperature. These results suggest that Jersey cows be more widely used in the warmer regions of South Africa.

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