Comparison between the coat temperature of the eland and dairy cattle by infrared thermography

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Abstract

Little is known about the thermoregulatory response of the eland, a tropical animal often raised in temperate climate. We compared the surface temperature ($T_s$) of the eland with that of similarly sized Holstein–Friesian dairy cattle at three different ambient temperatures ($T_a$) to get better evidence about thermal response. The $T_s$ of all body areas (neck, dewlap, trunk, body forepart, barrel, body hind part, forelimb and rear limb) did not differ at $T_a 29.2 \pm C$, but at $T_a 12.5 \pm C$ all the areas of the eland (except the neck) had lower mean $T_s$ than those areas in cattle. At $T_a 0.4 \pm C$, only the eland dewlap had a lower $T_s$ and the eland neck had a higher $T_s$ than that in cattle.

Keywords: Coat surface temperature; Eland; Dairy cattle; Infrared thermography

1. Introduction

There has been recent interest to breed the eland ($Taurotragus oryx$) for meat production in Europe (Kotrba and Ščevlíková, 2002). One of the possible concerns with this is that the eland, an animal originating from the tropics, might not be liable to suffer excessive body heat loss at low ambient temperatures ($T_a$), since they are not used to temperate climatic zone conditions. Despite this concern, the thermoregulatory responses of the eland are unknown outside of Africa. In a study by Taylor and Lyman (1967), it was shown that the metabolic rate of elands in Africa increased at $T_a$’s below 20°C. These authors suggested that the eland dissipated body heat more intensely than cattle ($Bos taurus$), namely Hereford steers.

Non-evaporative heat loss is determined by the animal-to-environment temperature gradient and by the amount of body surface area (Berman, 2003). Thus, the thermoregulatory strategy of an animal, based on the assumption of stable deep body temperature, should be aimed at minimizing the gradient between their coat surface temperature ($T_s$) and the temperature of the environment, since this will greatly reduce the flow of heat (Cena and Monteith, 1975). Infrared thermography has previously been used to accurately measure, from a distance, $T_s$ in furred animals (Klir and Heath, 1992; Speakman and Ward, 1998) and to evaluate the heat loss in flying birds (McCafferty et al., 1998). Use of this technology has also been shown to be suitable for demonstrating the distribution of $T_s$ on the human body (Jányky et al., 2003).

Our aim was to determine the $T_s$ of the eland and its distribution at different $T_a$’s. For comparison, we chose Holstein–Friesian dairy cattle, which are well adapted to the climate of Middle Europe. We hypothesized that the eland would have higher $T_s$ at low $T_a$ than the local cattle, as could be expected from the origin of these similarly sized mammals and their abilities to adapt to their environment (Bradley and Deavers, 1980).
2. Materials and methods

2.1. Animals

Seven eland females (four 4-year-olds; mean weight ± S.D., 350 ± 24.0 kg and three 5–8-month-olds, 111 ± 8.5 kg) and seven Holstein–Friesian female dairy cattle (all 4 years old; 483 ± 30 kg) were kept under open air conditions in the Czech Republic. The eland grazed freely in a 2.2 ha paddock and were supplemented with hay (ad libitum) during the experiment. The dairy cattle were fed a total mixed ration (ad libitum) that was added twice a day to meet their nutritional requirements for milk production. All animals had free access to a barn, which serves as winter housing. The elands were captive born in Dvůr Králové Zoo (Czech Republic) and were the fifth captive generation after their import from East Africa between 1969 and 1972 (Vágner, 1974). The use of the thermographic camera on the animals was approved by an ethical committee.

2.2. Measurements

We measured $T_s$ at three different $T_a$ on the eland farm and cattle farm (Czech Republic), both of which were loose-housing systems with free access to an outdoor area. Measurements were taken in the morning between 10:00 and 11:00, and were always taken on the left side of the body to avoid any effect of possible pregnancy. Temperature was recorded while the animals were motionless and without any restraint, separation or handling, because we assumed that these could stress the animals and, thus, influence the $T_s$ as was demonstrated by Vianna and Carrive (2005).

The $T_s$ was recorded perpendicularly at a 5-m distance using a thermographic camera (AGA 570 DEMO; AGEMA Infrared Systems AB, Danderyd, Sweden), with a 24’ lens, automatic calibration and an accuracy of 0.1 °C. The recordings from this camera were stored on a PCMCIA Camera Card 160 MB ATA. The $T_a$ and relative humidity ($R_h$) were recorded by a TESTO 415 (TESTO Inc., Flanders, USA) and the velocity of the air ($v$) was recorded by a TESTO 615 (TESTO Inc., Flanders, USA). We calculated a mean value for each microclimatic factor, based on five measured values, and calculated a temperature humidity index (Table 1) for both species to enable the comparison of thermal load during thermography measurement according to the methods of Hahn and Mader (1997).

Thermograms of the eland and dairy cattle body area surfaces were analyzed using a computer program (Irwin 5.3.1, AGEMA Infrared Systems AB, Danderyd, Sweden). Using this software, we defined eight body areas: neck, dewlap, trunk, body forepart, barrel, body hind part, forelimb and rear limb (Fig. 1), and calculated the mean $T_s$ for each measured area on each animal.

2.3. Statistics

Data were analyzed using the SAS System V 9.1 (SAS Institute Inc., Cary, NC). To normalize the $T_s$ data, we identified an appropriate power transformation by computing the Box-Cox family of power transformations using a macro in SAS (Timm and Mieczkowski, 1997). The associations between the mean $T_s$ of the described body areas (neck, dewlap, trunk, body forepart, barrel, body hind part, forelimb and rear limb) of the eland and Holstein–Friesian cattle measured at three different $T_a$'s were tested using a general linear mixed model (GLMM). In this model, the mean $T_s$ of the individual body areas was included as a dependent variable. The independent fixed effects consisted of the class variable ‘species’—eland or cattle—and the continuous variable the ‘weight’ and ‘ambient temperature’ nested within species. To account for different ages of the elands, this effect (‘age’—1 or 4 years) was nested within the interaction of species and ambient temperature. To account for repeated measures on the same animal across different body areas, the analysis was performed using the individual animal nested within species (eland or cattle) as a random factor, using PROC MIXED. The significance of each fixed factor in the GLMM was assessed using an $F$-test.

In this unbalanced design with more than one effect, the arithmetic mean for each group did not accurately reflect the response for the group, since it did not take into account the other effects in the model. Therefore, we used least-squares means (LSMEANs) instead. The LSMEANs

### Table 1

<table>
<thead>
<tr>
<th>Measurement</th>
<th>THI eland</th>
<th>THI cattle</th>
<th>$v$ eland</th>
<th>$v$ cattle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>72.1</td>
<td>77.1</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>53.3</td>
<td>57.4</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>38.4</td>
<td>37.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

THI represents the temperature humidity index and $v$ represents the velocity of the air (m s$^{-1}$).
were computed for each class and differences between classes were tested using a t-test. For multiple comparisons, we used the Tukey–Kramer adjustment.

3. Results

The final GLMM showed that the effect of ‘species’ was significant for the $T_s$ of the trunk ($F = 10.80; \text{d.f.} = 1, 30; P = 0.003$), dewlap ($F = 45.26; \text{d.f.} = 1, 23.7; P < 0.001$), barrel ($F = 12.74; \text{d.f.} = 1, 30; P = 0.001$), body hind part ($F = 8.06; \text{d.f.} = 1, 22.7; P = 0.009$), forelimb ($F = 11.93; \text{d.f.} = 1, 30; P = 0.002$) and rear limb ($F = 21.40; \text{d.f.} = 1, 30; P < 0.001$).

The effect of ‘weight’ was not significant for the $T_s$ and was therefore dropped from the GLMM. The effect of ‘ambient temperature’ (nested within species) on $T_s$ was found to be significant in the trunk area ($F = 141.92; \text{d.f.} = 4, 30; P < 0.001$), dewlap ($F = 120.58; \text{d.f.} = 4, 27.2; P < 0.001$), neck ($F = 98.73; \text{d.f.} = 4, 30; P < 0.001$), body forepart ($F = 142.01; \text{d.f.} = 4, 30; P < 0.001$), barrel ($F = 120.35; \text{d.f.} = 4, 30; P < 0.001$), body hind part ($F = 430.51; \text{d.f.} = 4, 13.2; P < 0.001$), forelimb ($F = 121.51; \text{d.f.} = 4, 30; P < 0.001$) and rear limb ($F = 124.20; \text{d.f.} = 4, 30; P < 0.001$) within both species. Both elands and cattle always had lower $T_s$ when they were measured at lower $T_a$, as demonstrated in the trunk area (Fig. 2). The mean $T_s$s did not differ between the elands and cattle at $T_a 29.2 \degree C$ for any of the surface areas (Fig. 3). At $T_a 12.5 \degree C$, elands had lower mean $T_s$s in the areas of the trunk, dewlap, barrel, body forepart, body hind part, forelimb and rear limb. The mean neck and dewlap $T_s$s were the only areas that differed between the species at $T_a 0.4 \degree C$. At this $T_a$, the eland dewlap had a lower mean $T_s$ and the eland neck had a higher mean $T_s$ than those areas of the cattle.

The effect of ‘age’ (nested within the interaction of species and ambient temperature) on $T_s$s of the eland was revealed in the forepart ($F = 11.58; \text{d.f.} = 3, 30; P < 0.001$), barrel ($F = 10.85; \text{d.f.} = 3, 30; P < 0.001$), body hind part ($F = 10.49; \text{d.f.} = 3, 6.94; P = 0.006$) and trunk ($F = 9.93; \text{d.f.} = 3, 30; P < 0.001$) areas. The 1-year-old elands had lower $T_s$s in those body areas in comparison to the 4-year-old ones at $T_a 12.5 \degree C$. The 1-year-old elands had lower mean $T_s$s at $T_a 12.5 \degree C$ in the forepart, barrel, body hind part and trunk areas compared with the same areas in cattle. The 4-year-old elands did not differ from cattle at $T_a 12.5 \degree C$. At $T_a 0.4 \degree C$, the $T_s$s of both the 1- and 4-year-old elands did not differ from cattle in the forepart, barrel, body hind part and trunk areas.
4. Discussion

The drop in cattle $T_a$ as a response to low $T_a$ is similar to the findings of Knížková et al. (2002) and Zahner et al. (2004). Until now, $T_a$ has never been examined in the eland. Taylor and Lyman (1967) found that elands exhibited more intensive dissipation of body heat than Hereford cattle at $T_a$ below 20 °C. Therefore, we presumed higher $T_a$ in elands than in cattle at low $T_a$. Contrary to this presumption, the $T_a$ of elands was lower or similar to cattle. Hartfiel et al. (1985) reported that domestic sheep (Ovis ammon L. aries) surpassed roe deer (Capreolus capreolus) in their ability to adapt to low temperatures because of lower $T_a$, which was explained by better insulation in sheep. On the basis of that principle, the elands showed similar adaptation to ambient temperatures above 0 °C in comparison to cattle.

According to Berman (2004), body insulation should be maximal at the lower critical temperature (LCT) of an animal, and at temperatures below their LCT animals must increase their heat production to maintain homeostasis. At temperatures below the LCT, non-evaporative heat loss increases linearly as $T_a$ decreases (Morgan et al., 1997). Most tropical animals have a LCT that is above 20 °C (Scholander, 1955). Taylor and Lyman (1967) found that the eland, restrained in a climatic chamber in Africa, had a LCT of 20 °C. Despite this fact, in several areas where elands can be found in Africa, the $T_a$ may substantially drop below 0 °C (Fuller et al., 1999). It has been suggested that elands accumulate heat during warmer days and dissipate this heat during colder nights (Taylor and Lyman, 1967). Contrary to this, the results of the present study suggest that the eland can adapt to the cold very well and can decrease their $T_a$ in low $T_a$, similar to cattle. This may reduce non-evaporative heat loss and possibly also decrease their LCT. Lowering of the LCT in homeotherms has previously been described by Korhonen and Harri (1986) as a more effective strategy than the energy-expensive increase of metabolism for heat production. Our findings fit well with practical experience of the energy-expensive increase of metabolism for heat production. Our findings fit well with practical experience of heat loss and possibly also decrease their LCT. Lowering of daily temperatures that elands were able to stay outside the barn until the mean daily $T_a$ dropped below 3.3 °C.

The impact of $T_a$ on an animal body can be determined by observing the distribution of $T_a$. The peripheral areas of mammals have been found to have predominantly lower $T_a$ at low $T_a$ because these areas undergo vasoconstriction first (Scholander, 1955). For example, reindeer (Rangifer tarandus) were reported to maintain the temperature of the distal areas of their bodies at just a little over freezing even at $T_a$ –22 °C to minimize the emission of heat (Irving and Krog, 1955). In our study, the limbs and dewlap of the eland and cattle had the lowest $T_a$ at all the $T_a$’s tested. In comparison with cattle, the eland’s limbs had lower $T_a$ at 12.5 °C, but we did not detect any differences at $T_a$ 0.4 °C. In a thermographic study by Zahner et al. (2004) on cattle, the lowest $T_a$ was also detected in the limbs as animals responded to low ambient temperatures.

Phillips and Heath (1995) compared the $T_a$ of 29 mammals and reported that large animals can regulate heat exchange better in cold $T_a$ than small ones. Moreover, it has been reported that adult cattle lose less heat in the cold than calves do (Webster, 1971). On the contrary, in our study, the eland calves had lower $T_a$ at 12.5 and 0.4 °C than the adults in the forepart, barrel, body hind part and trunk areas. Even though we did not measure the external insulation of the animals, the most plausible explanation for our finding is that the calves had a better-quality fur layer in these areas than the adults did.

At low $T_a$, the elands showed their protective response to decrease non-evaporative heat loss by lowering $T_a$, which was comparable to that observed in dairy cattle. Therefore, ambient temperatures above 0 °C seem to be within the eland’s thermoregulation limits and, hence, it is plausible to believe that the eland can adapt well to low temperatures.

5. Conclusions

We used infrared thermography to determine the coat surface temperature of seven captive eland females in different ambient temperature conditions and compared them with that seen in cattle. Contrary to expectation, the elands exposed to cold environmental temperatures had low surface temperatures, similar to cattle. This suggests that the eland has the potential to adapt to winter housing conditions in temperate climatic zones with inside temperatures above 0 °C.

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