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Effects of cold conditions on heat production by young sambar (*Cervus unicolor*) and red deer (*Cervus elaphus*)

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SUMMARY

An experiment to measure the effects of cold conditions upon heat production in young sambar (*Cervus unicolor*) and red deer (*Cervus elaphus*) was conducted during winter 1994, at Massey University, Palmerston North, New Zealand (NZ), using four young animals of each species. Animals were fed a pelleted concentrated diet (total N 29 g/kg DM; 11·9 MJ metabolizable energy (ME)/kg DM) at approximately maintenance ME intake (MEI). Hair coat characteristics were measured on samples cut from a patch on the mid-side of the body. Pairs of animals (one sambar and one red deer) were confined in two open circuit calorimetry chambers (one deer in each chamber) for 18-day periods, and oxygen consumption was measured at 20 and 5 °C, with and without simulated wind (6 km/h). Heat production was calculated as 20·5 MJ/l oxygen consumed.

Hair coats of sambar deer were less deep, lighter in weight (g/m^2) and contained a lower proportion of undercoat than those of red deer. Fibre length of both guard hairs and undercoat were shorter in sambar deer than in red deer, whilst fibre diameter of both guard hairs and undercoat was greater in sambar deer. Heat production (HP) at 20 °C was lower in sambar than in red deer ($P < 0{\cdot}05$; 0·46 *v.* 0·48–0·53 MJ/kg W$^{0{\cdot}75}$ per day). Increases in HP from 20 to 5 °C and from 20 °C to 5 °C W (i.e. with wind effect) were greater in sambar than in red deer ($P < 0{\cdot}01$; 34 *v.* 16% and 44 *v.* 20%, respectively). Calculated lower critical temperatures (LCT) were higher for sambar than for red deer ($P < 0{\cdot}10$) both in the absence (0 km/h; 11·6 *v.* 8·9 °C) and in the presence of wind (6 km/h; 14·0 *v.* 11·1 °C). Under field conditions, young sambar deer are likely to require more shelter and better feeding during cold weather than do red deer.

INTRODUCTION

Sambar deer (*Cervus unicolor*) are the largest of the tropical deer, with their natural distribution stretching from India throughout South-East Asia to the Philippines (Whitehead 1972). Although they have been successfully introduced to cooler temperate countries, such as New Zealand (Harris 1971), no data are available on their degree of tolerance to inclement weather conditions.

Exposure of animals to conditions below their lower critical temperature (LCT) causes an increase in heat production. This increase will result in a decrease in growth rate or a decrease in feed conversion efficiency or, at worst, could cause death (Holmes & McLean 1975). Compared to red deer (*Cervus elaphus*), the hair coat of sambar deer is coarser and sparser, with little undercoat (down fibres) developed in the winter (Semiadi 1993). During cold weather, sambar deer may be more susceptible to cold conditions than red deer, as a result of poorer body insulation. The objectives of this study were to measure the effects of low temperature and simulated wind on heat production in young sambar and young red deer during winter.

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MATERIALS AND METHODS

Experimental design

Four young sambar stags and three young red deer stags and one young red hind were used in the study. Animals were fed on a pelleted concentrated diet at approximately maintenance level of metabolizable energy intake (MEI). Oxygen consumption was measured at environmental air temperatures of 20

Table 1. *Mean values for age (days, S.E.) and liveweight (kg, S.E.) of young sambar and red deer in winter 1994 (n = 4/species)*

	Sambar deer	Red deer
Age (days)	165 (9·8)	202 (12·1)
Liveweight (kg)	45·1 (4·37)	49·8 (1·98)

and 5 °C, with and without simulated wind (6 km/h), in open circuit respiration chambers at the Animal Physiology Unit, Massey University, New Zealand (NZ). The trial commenced on 18 June 1994 and concluded on 8 September 1994, coincident with the winter period in New Zealand (NZ).

Animals

Thirteen deer calves (sambar and red deer) were artificially reared from birth, using the procedures described by Semiadi *et al.* (1993). Four sambar and four red deer were then selected for use in the calorimeters based on good temperament. Details of the age and weight of the deer used are shown in Table 1. Differences in age between the two species were due to sambar deer calving later than red deer in NZ (Semiadi *et al.* 1994). Pairs of animals (one sambar and one red deer) were confined in two open circuit calorimetry chambers (one deer in each chamber) for periods of *c.* 18 days and were weighed at the beginning and end of each period.

Diet

All animals were fed a pelleted concentrated diet, comprising barley (39·8%), bran/pollard (23·0%), brewers grain (5·0%), soyabean (10·0%), lucerne (15·0%), molasses (4·0%), salt (1·0%), lime (1·5%), dicalcium phosphate (0·5%) and vitamin mix (0·2%). The diet contained 29 gN/kg DM, organic matter digestibility (OMD) was 81·1% DM and calculated metabolizable energy (ME) was 11·9 MJ/kg DM. Each deer was fed an amount which supplied 0·52 MJ ME/kg $W^{0.75}$, the maintenance requirement measured for red deer in a previous study (Fennessy *et al.* 1981). There are no corresponding data for sambar deer.

Calorimetry and rectal temperature

Calorimetric measurements were carried out in two open circuit respiration chambers, generally as described by Holmes (1973). However, the composition of air samples drawn from the ingoing and exhaust airstreams were measured by a new paramagnetic gas analyzer (Servomex 1100, UK). The analyses were carried out on aliquot representative samples collected at a constant rate during the 24 h period (*c.* 7000 ml). Heat production was calculated from oxygen consumption using the equation of McLean (1972):

$$\text{Heat produced} = 20{\cdot}5 \times \text{litres oxygen consumed (MJ/day)} \quad (1)$$

Air temperature in the calorimetric chambers was controlled at 20 °C (expected to be within the thermoneutral zone) and at 5 °C (expected to be below the lower critical temperature). Simulated wind (*c.* 6 km/h) was generated by a propeller fan (24 cm diameter). Recordings were conducted after the animals had become accustomed to the calorimeters, with the sequence of measurements being as shown in Table 2.

Table 2. *Sequence in which the animals were exposed to the treatments during winter 1994*

Air temperature (°C)	Wind speed (km/h)	Day of recording
20*	0	1–8
20	0	9–10
5	0	11
5	6	12
5	0	13
5	6	14
20	0	15
20	6	16
20	0	17
20	6	18

* Acclimatization period.

Rectal temperature was measured when each animal was removed from the chamber and hand-restrained in a darkened room. A mercury in glass thermometer was then inserted rectally for 4–5 min.

Measurements of hair coat characteristics

Measurements of hair coats were made prior to the animals going into the chambers. Hair coat depth was measured using a rigid steel ruler at the mid-side of the body. Hair coat from a measured area (*c.* 40 cm²) of the mid-side was then clipped using an electric clipper (Golden A5, Oster, USA), *c.* 2 mm above the skin, collected and weighed at 60% relative humidity and 20 °C. Subsamples of the clipped hair were then separated into guard hairs and undercoat, weighed and the proportion (% weight) of each calculated. Twenty guard hairs and ten undercoat fibres were then measured for length using a rigid steel ruler, and diameter was measured at the mid-point of each fibre using a projection microscope (Reichert Jung, Austria) at 50× magnification for guard hairs and 500× magnification for undercoat fibres. The diameters of guard hairs in both sambar and red deer were bigger at the base and finer at the tip, although this was more pronounced in sambar than in red deer. Thus, measuring the diameter of guard hairs at the mid-point was assumed to provide a representative measurement.

Data calculations and statistical analysis

Heat production (HP) was expressed as KJ/kg $W^{0.75}$, MJ/m^2 surface area (calculated as liveweight $Kg^{0.633} \times 0.097$; Brody 1945) and as MJ/m^2. $\triangle$ °C (where $\triangle$ °C = rectal temperature – air temperature). The HP data recorded in the sequence shown in Table 2 was tabulated into five categories as follows: 20 °C(i) (at the beginning of trial), 5 °C, 5 °C W (with wind effect), 20 °C(ii) (at the end of trial) and 20 °C W (with wind effect). Body conductance (the rate of non-evaporative heat loss per m^2 of surface area per degree centigrade thermogradient between deep body tissues and surrounding environment) at 5 °C and 5 °C W, was calculated as described by Holmes & McLean (1975) and is shown in Eqn 2, where 0·83 is sensible heat loss as a proportion of total heat produced by young calves (Gonzalez-Jimenez & Blaxter 1962).

$$\text{Body conductance} = (\text{MJHP at } 5\,°\text{C}/\text{m}^2 \triangle\,°\text{C}) \times 0{\cdot}83 \quad (2)$$

Insulation can be calculated as the reciprocal of body conductance.

Lower critical temperature (LCT) was calculated as described by Holmes & McLean (1975; Eqn 3).

$$\text{LCT } (°\text{C}) = T_R - \frac{(\text{MJHP at } 20\,°\text{C(ii)}/\text{m}^2) \times 0{\cdot}83}{\text{Body conductance at } 5\,°\text{C}} \quad (3)$$

where T_R = rectal temperature (°C).

All data were subjected to one-way analysis of variance using the Statistical Analysis System package (SAS 1987).

RESULTS

Hair coat

Relative to red deer, the coat of sambar deer was of lower fibre depth ($P < 0{\cdot}05$), lower weight (g/m²: $P < 0{\cdot}01$), and of shorter length for both guard hairs ($P < 0{\cdot}01$) and for undercoat fibres ($P < 0{\cdot}05$). Fibre diameter was larger for sambar deer than for red deer, for both guard hairs and for undercoat fibres ($P < 0{\cdot}001$; Table 3). Undercoat fibres were present in all four red deer, but in only two sambar deer. In deer where undercoat was present, its proportion of the total coat weight was lower for sambar than for red deer ($P < 0{\cdot}001$).

Heat production

The mean values for HP expressed as KJ/kg $W^{0.75}$, MJ/m^2 surface area and MJ/m^2 $\triangle$ °C are shown in Table 4. The values for sambar deer were lower ($P < 0{\cdot}05$) at 20 °C(i) and 20 °C(ii) and higher ($P < 0{\cdot}05$) at 5 °C and 5 °C W than those for red deer. The decrease in heat production at 20 °C, which occurred for red deer between the first (i) and second (ii) measurements, suggests that these deer became more accustomed to and more relaxed in the calorimeters during the period of the measurements, which is consistent with observed behaviour. The mean values for body conductance calculated at 5 °C and 5 °C W are also shown in Table 4 (these are the most relevant values for conductance, because evaporative heat loss would have been reduced to a minimum rate in these cold conditions). At 5 °C and 5 °C W the values of conductance for sambar deer were slightly higher ($P < 0{\cdot}05$) than those for red deer.

Table 3. *Fibre characteristics of young sambar and red deer during winter 1994 (n = 4/species)*

	Sambar deer	Red deer	S.E.
Depth of fibre coat (mm)	26·8	30·1	0·68
Weight of fibre coat (g/m²)	114	255	14·4
Proportion of undercoat (% total weight)	0·7*	9·6	0·87
Fibre length			
Guard hairs (mm)	44·0	53·9	1·07
Undercoat (mm)	20·3*	30·2	2·35
Fibre diameter			
Guard hairs (μm)	277·0	248·5	5·07
Undercoat (μm)	18·0*	11·5	0·65

* $n = 2$; remaining two animals had no undercoat fibres.

The increase in HP at 5 °C and 5 °C W when compared with 20 °C(ii) are shown in Table 5. Exposure to colder conditions and wind caused much larger increases ($P < 0{\cdot}01$) in HP in sambar than in red deer.

Lower critical temperature

Values for LCT were calculated by assuming that values for HP measured at 20 °C(ii) represented minimum thermoneutral HP, and that values for body conductance measured at 5 °C and 5 °C W represented minimum values below the LCT. Lower critical temperature values for sambar deer at 0 and 6 km/h were higher ($P < 0{\cdot}10$; Table 6) than those for red deer.

DISCUSSION

The present study shows that sambar deer are less well equipped to resist cold conditions than red deer. They demonstrated much larger increases in HP at 5 °C and 5 °C W than red deer, partly because body conductance of sambar deer was slightly higher (or insulation was slightly lower) and partly because their

Table 4. *Mean values for heat production and calculated body conductance of young sambar (S) and red deer (R), measured during winter 1994 (n = 4/species)*

Temperature (°C)...		20 (i)	5	5	20 (ii)	20
Wind speed (km/h)...		0	0	6	0	6
Heat production (HP)						
KJ/kg $W^{0.75}$/day	S	460	615	659	460	490
	R	528	557	576	481	489
S.E.		11·5	14·9	17·9	6·6	7·0
MJ/m^2 surface area	S	7·4	9·9	10·6	7·4	8·0
	R	8·6	9·1	9·4	7·9	8·0
S.E.		0·19	0·22	0·26	0·12	0·12
MJ/m^2 △ °C	S	0·43	0·31	0·34	0·42	0·45
	R	0·50	0·29	0·31	0·47	0·48
S.E.		0·013	0·008	0·009	0·012	0·012
Body conductance	S		0·26	0·28		
(MJ/m^2 △ °C) × 0·83	R		0·24	0·25		
S.E.			0·006	0·007		

Table 5. *Mean values for increases (%)* in heat production (MJ/m^2 surface area) in young sambar and red deer during winter 1994 (n = 4/species)*

Temperature (°C)...	5	5
Wind speed (km/h)...	0	6
Sambar deer	+34	+44
Red deer	+16	+20
S.E.	3·4	4·7

* Calculated as

$$\frac{(\text{HP at 5 °C} - \text{HP at 20 °C(ii)})}{\text{HP at 20 °C(ii)}} \times 100$$

and as

$$\frac{(\text{HP at 5 °C W} - \text{HP at 20 °C(ii)})}{\text{HP at 20 °C(ii)}} \times 100.$$

Table 6. *Mean values for lower critical temperature (°C) calculated with and without wind effect in young sambar and red deer, during winter 1994 (n = 4/species)*

Wind speed (km/h)	0	6
Sambar deer	11·6	14·0
Red deer	8·9	11·1
S.E.	0·94	0·98

thermoneutral HP was slightly lower than the corresponding values for red deer (Table 4). The higher conductance (lower insulation) in the sambar deer is consistent with their lower values for coat depth and weight/m^2 than red deer (Table 3). In addition, the shorter fibres and the smaller proportion of finer fibres (undercoat) in the coat of sambar deer would also have contributed to poorer insulation properties. The differences between species in body conductance and weight of coat fibre in the present study are similar to the differences between Jersey and Holstein calves (Table 7). The importance of the insulation provided by the coat of deer was demonstrated by the 91% increase in HP caused by clipping and removing the coat of the white-tailed deer (*Odocoileus virginianus*) in winter (Silver *et al.* 1971).

Lower critical temperature values in the present experiment have been compared with those for other ruminant species in Table 8. As would be expected, increasing coat length/depth was associated with lower values for LCT in both sheep and black-tailed deer. Compared to cattle and to black-tailed deer, values for LCT seem high in relation to coat depth for the young deer of both deer species used in the present study and especially for sambar deer. Adult black-tailed deer kept under much colder North American winter conditions are thus more resistant to cold than young sambar and red deer kept under warmer winters in NZ. However, they are similar to the value of 12 °C for young, 37 kg, Friesian calves (Holmes & McLean 1975).

The values of 528 and 481 KJ/kg $W^{0.75}$ for HP by the red deer at 20 °C(i) and 20 °C(ii) are similar to those reported in other studies (464 KJ/kg $W^{0.75}$, Simpson *et al.* 1978; 520 KJ/kg $W^{0.75}$, Suttie *et al.* 1987). The present values show that the red deer required *c.* 15–17 days in the calorimeter before their thermoneutral HP had reached minimum values. Careful and quiet management of these animals is obviously an important consideration in the measurement of realistic minimal values of HP.

Table 7. *Comparisons in body conductance* ($(MJ/m^2 \triangle °C) \times 0{\cdot}83$) *and coat fibre weight* ((g/m^2)) *between young deer and young cattle*

Species	Heat conductance	Fibre weight	Author
Young sambar deer	0·26	114	Present study
Young red deer	0·24	255	Present study
Jersey calves	0·25	164	Holmes & McLean (1975)
Holstein calves	0·22	349	Holmes & McLean (1975)

Table 8. *Comparisons of lower critical temperature (LCT; °C) and fibre length/depth (mm) in different ruminants*

Species	LCT (°C)	Fibre length/depth (mm)	Author
Deer			
Young sambar*	11·6	27	Present study
Young red*	8·9	30	Present study
Young black-tailed*	5	17	Parker (1988)
Adult black-tailed*	−6	27	Parker (1988)
Steers	7	8	Blaxter (1962)
Sheep	22	10	Blaxter (1962)
	9	50	Blaxter (1962)
	−3	100	Blaxter (1962)

* All deer studies conducted during winter, using deer with their winter hair coats.

The practical implications of these data are that weaner deer of both species require shelter and good feeding during winter, but that sambar deer require more shelter and better feeding management during this time than red deer. This is due to both the higher LCT in sambar than in red deer and also to the lower coat insulation in the sambar. In their natural habitat, sambar deer can be found up to altitudes of 2000 m (Whitehead 1972). At this high altitude they are unlikely to be exposed to temperatures > 10–12 °C in the tropics. Field experiences with weaner and adult sambar deer at latitude 40° 14′ S and longitude 175° 16′ E in NZ, with mean monthly temperature ranges of 9–20 °C, show that they can live and grow satisfactorily provided that they have access to natural or artificial shelter and feed supplements during winter. As sambar deer calve all year round (Semiadi *et al.* 1994), mating is another aspect of management which must be changed so that calving during winter is avoided in a farming situation.

It can be concluded from the present studies that young sambar deer had shorter and lighter coats than young red deer and that this was associated with higher body conductance (lower insulation) in sambar deer. Consequently the young sambar deer had higher values for LCT than young red deer and exhibited greater increases in HP when exposed to colder conditions.

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