ROLE OF COAT COLOUR IN BODY HEAT REGULATION AMONG GOATS AND HAIRY SHEEP IN TROPICS[1]

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ABSTRACT - This experiment was conducted during the hottest and the leanest period of the year in the tropical semi-arid northeast of Brazil to evaluate the relative response of black and white varieties (with the colour of skin and of hair being the same) of goats and hairy sheep to grazing under direct solar radiation. There was a marked increase in midside-skin (MS), ear-skin (ES) and rectal temperatures (RT) and respiratory rate (RR) at 2 P.M. The afternoon increase was more in sheep in MS, RT and RR, but ES increased more in goats. Black animals had uniformly higher MS. White sheep had higher ES but in goats colour had no effect. Right ES was higher in sheep and there was some tendency of higher right ES in general. The black goats respired at much higher rates than the white, but in sheep, colour did not influence RR. Colour of animals did not influence RT. There was significant day-to-day variation, possibly associated with small fluctuations in environmental temperature, in MS, ES and RR but not in RT. The results indicate that goats appear to be better adapted than hairy sheep and white goats better than black goats under local climatic conditions.

Index terms: solar radiation, tropical region, adaptability, physiological response.

INFLUÊNCIA DA COR DA PELAGEM NA REGULAÇÃO DO CALOR EM CAPRINOS E OVINOS SEM-LÃ NO TRÓPICO

RESUMO - Este experimento foi conduzido na região tropical do nordeste Brasileiro para avaliar a resposta relativa ao calor dos caprinos e ovinos sem-lã de pelagem (pele + pêlo) branca e preta em pastejo e expostos diretamente à radiação solar. Houve um aumento marcante nas temperaturas da pele da costela (PC), pele da orelha (PO) e retal (TR) e no rítmo respiratório (RR) às 14h. À tarde, a elevação foi maior em ovinos na PC, TR e no RR, mas PO aumentou mais nos caprinos. Animais pretos tinham, uniformemente, maior PC. Os ovinos brancos exibiram maior PO, mas no caprinos a cor não influenciou. ES direita foi superior em ovinos e houve tendência da PO direita ser, em geral, superior. Caprinos de cor preta apresentaram maior elevação no RR do que os de cor branca, mas nos ovinos a cor não influenciou o RR. Cor da pelagem não teve influência na TR. Houve uma variação diáriá significante na PC, PO e RR, mas não na TR, possivelmente associado com flutuações na temperatura ambiental. Resultados indicam que caprinos parecem ser melhor adaptados do que ovinos sem-lã e caprinos brancos melhor que caprinos pretos sob as condições climáticas locais.

Termos para indexação: região tropical, radiação solar, adaptabilidade, respostas fisiológicas.

INTRODUCTION

The importance of goats and hairy sheep in the tropical northeast of Brazil has been explained elsewhere (Figueiredo & Pant 1982, Figueiredo et al. 1982a, b and c). In crossbreeding programmes, different coat colour patterns, that appear in the progeny, may create some problem of choosing one coat colour for standardization of new breeds and genotypes. If colour of the animal has relevance to its adaptability under hot tropical environment, selection of animals on the basis of coat colour would be warranted. This experiment was planned to see if the most diverse, and common, black and white coat colour have different physiological reactions to grazing under sun during hottest and leanest dry months in this area and the extent to which the goats and hairy sheep differ in their response.

MATERIALS AND METHODS

The local goats are generally classified into four distinct types on the basis of their body colour pattern (Mason 1980, Shelton & Figueiredo 1981). The four types are very uniform and similar (Mason 1980) and perhaps do not differ much in their genotypes and performance (Figueiredo & Pant 1982, Figueiredo et al. 1982a). Among these four types, Canindé are almost totally black and Marota totally white. For this experiment, these two

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types were considered as two colour varieties of same genotype. In Santa Inês breed of hairy sheep (Figueiredo et al. 1982b), both black and white varieties occur (Figueiredo & Arruda 1980) in addition to the more common red colour. The terms 'black' and 'white' indicate colour of both the skin and the hair of the animals.

Ten females from each of the four groups of animals (black and white goats and sheep) were randomly selected. All females were adult and mature in their second or third parities. All were nonpregnant and nonlactating during the period of experimentation. These animals were brought to the experimental sheeds about a month prior to the experiment for acclimatization.

A pasture area was developed close to the experimental sheds. This area was fenced and all trees were cut and prunned to eliminate the possibility of any shade area for animals. During the dry months, most of the trees do not have any leaves and animals graze on whatever dry grass or vegetable matter is available on the ground.

The animals were let out of the sheds at about 8:30 A.M. and they returned at about 2 P.M. They were let out again at about 3:30 P.M. and returned at about 5 P.M. Water was available near the sheds but they were not allowed to drink water before the observations were recorded during the afternoon. Animals never appeared very thirsty and probably had sufficient access to water. Some hay was provided as supplementation in the grazing area and none of the animals suffered from any visible symptoms of disease during the entire period.

The animals remained in the sheds overnight and in the morning till the morning data were collected. Rectal temperature was measured with a clinical thermometer, midside skin and ear-skin temperatures were recorded on both left and right sides with a digital thermometer with sensitive probe, and respiratory rate was recorded by observing the flank movement. Attempts were made to bring the digital thermometer probe into close contact with skin surfaces. The order in which the records were collected was random. The morning temperature of the ear skin was mostly below 30°C and, for analysis, only the afternoon ear-skin temperature was considered. Four observations on different days, with at least a day's gap, were made on each animal during September/October.

The following statistical models were used for the analysis of data. In these models, morning *versus* afternoon (M), colour of animals (C), species (S), days (D) and right *versus* left sides of the animals (R) were all considered as main fixed effects and variations due to these and their all possible interactions were calculated.

Y = Midside-skin temperature

$$\begin{aligned} Y_{ijklmn} = {} & \text{Common-mean} + M_i + C_j + S_k + D_l + R_m + \\ & + (MC)_{ij} + (MS)_{ik} + (MD)_{il} + (MR)_{im} + (CS)_{jk} + \\ & + (CD)_{jl} + (CR)_{jm} + (SD)_{kl} + (SR)_{km} + \\ & + (DR)_{lm} + (MCS)_{ijk} + (MCD)_{ijl} + (MCR)_{ijm} + \\ & + (MSD)_{ikl} + (MSR)_{ikm} + (MDR)_{ilm} + \\ & + (CSD)_{jkl} + (CSR)_{jkm} + (CDR)_{jlm} + \\ & + (SDR)_{klm} + (MCSD)_{ijkl} + (MCSR)_{ijkn} + \\ & + (MCDR)_{ijlm} + (MSDR)_{iklm} + (CSDR)_{ijkm} + \\ & + (MCSDR)_{ijklm} + \text{Error}_{ijklmn}. \end{aligned}$$

Y = Afternoon ear-skin temperature

$$\begin{aligned} Y_{jklmn} = {} & \text{Common-mean} + C_j + S_k + D_l + R_m + (CS)_{jk} + \\ & + (CD)_{jl} + (CR)_{jm} + (SD)_{kl} + (SR)_{km} + \\ & + (DR)_{lm} + (CSD)_{jkl} + (CSR)_{jkm} + (CDR)_{jlm} + \\ & + (SDR)_{klm} + (CSDR)_{jklm} + \text{Error}_{jklmn}. \end{aligned}$$

Y = Rectal temperature

$$\begin{aligned} Y_{ijklm} = {} & \text{Common-mean} + M_i + C_j + S_k + D_l + (MC)_{ij} + \\ & + (MS)_{ik} + (MD)_{il} + (CS)_{jk} + (CD)_{jl} + (SD)_{kl} + \\ & + (MCS)_{ijk} + (MCD)_{ijl} + (MSD)_{ikl} + (CSD)_{jkl} + \\ & + (MCSD)_{ijkl} + \text{Error}_{ijklm}. \end{aligned}$$

Y = Respiratory rate

Same model as for rectal temperature.

In the analysis, the nonsignificant interactions were pooled and presented as such as one factor without merging them with the error term. The significant interactions were calculated and presented individually.

RESULTS

Results of analysis of variance are presented in Table 1 and means in Table 2. The mean values have been further subclassified according to significant interactions in Table 3. The maximum variation was caused by increase in the midside-skin temperature in the afternoon (M effect). The mean increase in the afternoon was 2.86°C and this was the largest difference caused by any other main factor studied in this experiment. The black animals (goats and sheep) had uniformly higher mean skin temperature than the white animals, the difference being 0.36°C, and colour of animals did

TABELA 1. Analysis of variance of skin and body temperatures and respiratory rates of goats and hairy sheep of different body colours in tropical northeast Brazil.

Source of variation	d.f.	Mean squares			
		Midside-skin temp (°C)	Afternoon ear-skin temp (°C)	Rectal temp (°C)	Respiratory rate per minute
Morning vs. afternoon (MA)	1	1309.59****		241.86****	123637.8****
Colour of animal	1	20.84****	34.19****	0.01^{ns}	2010.0*
Species	1	6.91***	304.59****	6.61****	5865.3***
Days	3	7.49****	9.24***	0.17^{ns}	2495.7***
Right vs. left side (RL)	1	0.76^{ns}	8.39**	-	-
Significant interactions					
MA x Species	1	52.61****	-	5.67****	1970.1*
MA x Days	3	3.65***	-	-	-
Colour x Species	1	-	37.54****	-	2111.5*
Species x Days	3	1.97(*)	-	-	-
MA x Colour x Species	1	-	-	0.69(*)	-
MA x Species x Days	3	3.10***	-	0.56*	-
Colour x Species x RL	1	-	6.45*	-	-
Pooled nonsignificant interactions	a	0.42^{ns} (46)	0.95^{ns} (23)	0.14^{ns} (20)	398.2^{ns} (23)
Error^{b}	576/288	0.64	1.24	0.17	409.8

Note: [a]degrees of freedom are presented alongwith the mean squares within parentheses.

[b]degrees of freedom for error are 576 for midside-skin temperature and 288 for other 3 characteristics.

^{ns}not significant ($P > 0.05$); (*) significant ($P < 0.05$); * significant ($P < 0.03$); ** highly significant ($P < 0.01$); *** highly signicant ($P < 0.005$); **** highly significant ($P < 0.0001$).

TABLE 2. Mean (one standard error) values of skin and body temperatures and respiratory-rates of goats and hairy sheep in tropical northeast Brazil.

Classification	Main effects	Midside-skin temperature (°C)	Afternoon ear-skin temperature (°C)	Rectal temperature (°C)	Respiratory rate per minute
	Overall mean	37.18	36.50	38.655	40.805
Morning vs. afternoon	1. Morning	35.75 (0.051)^{a}	below 30.00	37.79 (0.037)^{a}	21.15 (0.588)^{a}
	2. Afternoon	38.61 (0.038)^{b}	36.50 (0.062)	39.52 (0.027)^{b}	60.46 (2.186)^{b}
Species	1. Goats	37.28 (0.042)^{c}	37.47 (0.077)^{c}	38.80 (0.031)^{c}	36.53 (1.856)^{c}
	2. Hairy sheep	37.08 (0.047)^{d}	35.54 (0.098)^{d}	38.51 (0.034)^{d}	45.08 (1.295)^{d}
Colour	1. Black	37.36 (0.045)^{e}	36.17 (0.099)^{e}	38.66 (0.034)^{e}	43.31 (1.740)^{e}
	2. White	37.00 (0.044)^{f}	36.83 (0.076)^{f}	38.65 (0.030)^{e}	38.30 (1.447)^{f}
Righth vs. left side	1. Right	37.21 (0.041)^{g}	36.66 (0.088)^{g}	-	-
	2. Left	37.15 (0.04b)^{g}	36.34 (0.087)^{h}	-	-
Days	1. First day	36.88 (0.081)^{i}	36.27 (0.130)^{i}	38.61 (0.050)^{i}	37.22 (2.458)^{i}
	2. Second day	37.32 (0.052)^{k}	36.49 (0.131)^{i}	38.70 (0.050)^{i}	45.15 (2.203)^{j}
	3. Third day	37.36 (0.066)^{k}	36.99 (0.118)^{j}	38.69 (0.041)^{i}	45.97 (2.446)^{j}
	4. Fourth day	37.16 (0.050)^{j}	36.26 (0.110)^{i}	38.62 (0.045)^{i}	34.88 (1.901)^{i}

Note: The mean differences are expressed by superscripted letters.

TABLE 3. Means (standard errors) according to significant interactions of the skin and rectal temperatures and respiratory rate in goats and hairy sheep.

Midside-skin temperature (°C)			Afternoon ear-skin temp. (°C)			Rectal temp. (°C)			Respiratory rate per minute		
Main significant interaction	Interaction combinations	Mean temp. (S.E.)	Main significant interaction	Interaction combinations	Mean (S.E.)	Main significant interaction	Interaction combinations	Mean (S.E.)	Main significant interaction	Interaction combinations	Mean (S.E.)
MA.SP.DA.	MOR.GO.DA I	35.99 (0.203)	CL.SP.RL.	BL.GO.RT.	37.52 (0.141)	MA.SP.	MOR.GO	38.06 (0.043)	MA.SP.	MOR.GO.	19.35 (1.038)
	DA II	36.25 (0.095)		LF.	37.46 (0.190)		AFT.GO	39.54 (0.043)		AFT.GO.	53.70 (3.564)
	DA III	36.30 (0.107)		Mean over sides	37.49 (0.118)						
	DA IV	36.02 (0.099)					MOR.SH	37.51 (0.060)		MOR.SH.	22.95 (0.551)
	Mean over days	36.14 (0.067)		WH.GO.RT.	37.54 (0.149)		AFT.SH	39.51 (0.034)		AFT.SH.	67.23 (2.531)
	AFT.GO. DA I	38.31 (0.114)		LF.	37.38 (0.128)						
	DA II	38.48 (0.085)		Mean over sides	37.46 (0.098)				CL.SP.	BL.GO.	41.60 (2.92)
	DA III	38.55 (0.123)								WH.GO.	31.45 (2.29)
	DA IV	38.38 (0.079)		BL.SH.RT.	35.38 (0.224)						
	Mean over days	38.43 (0.051)		LF.	34.33 (0.223)					BL.SH.	45.03 (1.89)
	MOR.SH. DA I	34.48 (0.197)		Mean over sides	34.86 (0.158)					WH.SH.	45.15 (1.78)
	DA II	35.81 (0.124)									
	DA III	35.64 (0.160)		WH.SH.RT.	36.21 (0.182)						
	DA IV	35.51 (0.110)		LF.	36.19 (0.142)						
	Mean over days	35.36 (0.076)		Mean over sides	36.20 (0.115)						
	AFT.SH.DA I	38.74 (0.105)									
	DA II	38.73 (0.104)									
	DA III	38.96 (0.133)									
	DA IV	38.74 (0.110)									
	Mean over days	38.79 (0.057)									

Note: MA = Morning vs. afternoon; SP = Species of goats vs. hairy sheep; DA = Days 1 to 4 of experimente; MOR = Morning; AFT = Afternoon; GO = Goat; SH = Sheep; CL = Coat colour of animals; RL = Right vs. left side of animals; BL = Black coat colour; WH = White coat colour; RT = Right side; LF = Left side.

not interact with any other factor in the experiment. Goats, in general, had slightly higher skin temperature than sheep; 0.20°C difference was significant. There was a significant M x species interaction. The mean midside-skin temperature of goats in the morning was 0.78°C higher than in sheep. But in the afternoon, it was 0.36°C higher in sheep. The mean increase in the afternoon temperature was 2.3°C in goats and 3.5°C in sheep. The midside-skin temperature also significantly varied on different days. It was significantly lower on the first day, maximum during the second and third days and intermediate on the last day. There was some indication of a significant species x days interaction. The mean overall temperature of midside-skin varied slightly more in sheep than in goats on different days.

There was also a significant difference in the increase of afternoon temperature on different days (M x days interaction). On the first day, when mean morning temperature was lowest, the afternoon temperature increased by 3.29°C. On the last, third and second days, the increases were 2.87°C, 2.785°C and 2.575°C respectively. Thus, the extent of increase in the afternoon midside-skin temperature was negatively correlated with the overall morning temperature of the skin (r = -0.975). However, a careful perusal of data revealed that such a negative correlation was due to variation in the midside-skin temperature of sheep only. The M x species x days interaction was significant which meant that the magnitude of morning-afternoon difference in the skin temperature was different in sheep and goats on different days. An examination of means in Table 3 showed that the increase in afternoon temperature varied from 2.23°C to 2.36°C in goats on different days, but in sheep it varied from 3.38° to 4.26°C. Thus, the increase in midside-skin temperature of goats was constant without any relation to variations in the ambiental temperature and so if the morning skin temperature was high the afternoon skin temperature was also high (simple correlation = 0.97), although both the morning and evening skin temperatures can simultaneously be influenced by the variation in mean day time ambiental temperature. In sheep, the afternoon skin temperature had no relation with morning skin temperature and the higher increase in the afternoon simply indicated that the morning temperature had been lower on that particular day, and thus there was no correlation (r = 0.28) between morning and afternoon temperatures. But this behaviour on the part of the sheep resulted into an overall negative correlation (r = -0.98) between the morning skin temperature and the subsequent increase in the afternoon, as explained earlier.

The morning ear-skin temperature (henceforth mentioned as ear temperature) was almost always lower than 30°C and the digital thermometer used by us did not register temperature below 30°C. Of the 320 observations recorded for morning ear temperature, 280 were below 30°C and therefore not measurable and the remaining 40 observations gave a mean of 32.39°C. If all the 280 observations that were below 30°C are taken as 30°C. the mean obtained would be 30.299°C. Hence, although measurements of morning ear temperature were recorded, these were later ignored and analysis was made only of the afternoon ear temperatures.

The mean afternoon ear temperature was 36.5°C, which is 2.11°C lower than the mean midside-skin temperature in the afternoon. The goats had markedly higher, by 1.93°C, mean ear temperature than sheep. The white animals had slightly higher (by 0.66°C) ear skin temperature than the black ones. A significant colour x species interaction indicated that the effect of colour was different in the two species. In goats, there was practically no difference in the mean ear temperature between black and white colours (difference = 0.03°C). But in sheep, white animals had a mean ear temperature about 1.34°C higher than black animals.

A significant difference was also observed between the right and left (R effect) ear temperatures and the right ear had 0.32°C higher temperature. But most of this difference was due to one category of animals as indicated by a significant colour x species x R interaction. An examination of means in Table 3 revealed that the maximum difference between right and left sides in their ear temperatures was exhibited by black sheep, right ear exhibiting a higher temperature by about

1.05°C. In white sheep, the difference was only 0.09°C and not significant. In goats, the difference between sides (R) was marginally higher in white than black animals, but both these differences were small and not significant. However, in all the four categories (black and white goats and sheep) the right ear had higher values than left ear.

A significant difference was observed in the rectal temperature of goats and hairy sheep. The temperature of goats was about 0.29°C higher than hairy sheep. A marked variation, like in other characteristics studied, was observed between morning and afternoon (M effect) rectal temperatures, the mean difference being 1.73°C. However, the magnitude of M variation was different in the two species as indicated by a significant M x species interaction. The goats started with a relatively higher rectal temperature in the morning and it was increased by 1.48°C in the afternoon. The sheep had 0.55°C lower body temperature than goats in the morning but their body temperature increased by 2°C in the afternoon. On an overall basis, colour of the animals did not influence the mean rectal temperature and both black and white animals had almost identical rectal temperatures. The rectal temperature also did not vary between different days. Significant M x colour x species and M x species x days ($P < 0.05$ to 0.03) interactions were also obtained.

The respiratory rate also significantly varied between goats and hairy sheep. Sheep had higher mean respiratory rate than goats, the difference being 8.55 more respirations per minute. Maximum difference, however, was obtained between the morning and the afternoon (M effect). The afternoon respiratory rate was nearly 3 times the respiratory rate of the morning. A significant M x species interaction was observed and this showed that the rate of increase in respiration rate was different in goats and hairy sheep. A perusal of means in Table 3 revealed that whereas in goats the respiratory rate increased from 19.35 to 53.7 (increase being 34.35) respirations per minute, in sheep it increased from 22.95 to 67.23 (increase being 44.28). The mean respiratory rate of black animals was higher (43.31) than of white animals (38.30). There was also a significant colour x species interaction and means in Table 3 show that black goats respired at a much higher rate than white goats, but in sheep the respiration rate of black and white animals was practically the same. The white goats had significantly lower respiratory rate than all other categories of animals. The respiratory rate also varied during different days. Highest respiratory rate was recorded on the second and third days, minimum on the last day and intermediate on the first day.

DISCUSSION

This experiment mainly concerns with the determination of some physiological norms during the part of the year that constitutes the most stressful period. There are two main reasons that create an adverse environment for species like sheep and goats in this region: the scarcity of fodder and high ambiental temperature that may inhibit longer travels of animals in search of food (Arruda et al. 1984).

The fooder scarcity is known to cause growth to cease (Riera et al. 1982) and if supplementation is given during this period the total productivity can be much improved (Oliveira et al. 1982). Oliveira et al. (1982) have also suggested modifications in the management, like extended periods of grazing, to partially reduce effects of nutritional stress.

In this experiment, it was tried to demonstrate the direct physiological stress and the extent to which physiological attributes like body and skin temperatures and respiratory rates change in hot dry season as a result of grazing under sun on shadeless pastures.

Thus, what is being measured and explained are the external measurable responses of animals (Symington 1960a, b, c and d, Arruda & Pant 1984, Arruda et al. 1984) and not the internal regulations and mechanisms as a result of interaction between air temperature and physiological response of various internal organs (Jessen 1977 and 1981, Mercer & Jessen 1979, Boyne et al. 1981, Bisgard et al. 1982).

Also, it is necessary to define adaptability.

First of all, sweating animals tolerate heat better than panting animals (Bianca 1968) and hence animals that exhibit relatively lower respiratory rate under exposure to heat may be considered better adapted.

Secondly, through physiological homeostatic mechanisms, an animal exposed to exercise or solar radiation is able to maintain certain physiological attributes closer to their at-rest values (Sutherland 1968). Thus, only adaptability as determined by certain physiological responses is considered and not the productive adaptability of animals (Yousef et al. 1968).

In previous experiments (Arruda & Pant 1984, Arruda et al. 1984), no distinct species differences were observed in the body temperature. The main reason was that the breeds of sheep and goats used exhibited significant differences and the order in which breeds varied did not indicate any species-specific trend. Thus, one sheep breed had values intermediate to two goat breeds. This showed that hairy sheep and goats in northeast Brazil perhaps had similar modes of heat dissipation.

In this experiment, significant differences between species were found and, as only one breed each in goats and sheep was available this difference explains a confounded effect of breeds and species. This difference was much smaller than that observed between morning and afternoon temperatures. The morning-afternoon difference was almost of the same order as observed by Arruda et al. (1984) and similar to the difference observed before and immediately after exercise by Arruda & Pant (1984).

The Santa Inês breed exhibited much larger increase in the afternoon as compared to goats and this confirms previous results (Arruda & Pant 1984, Arruda et al. 1984) where Santa Inês exhibited higher rise in body temperature and exhibited slower recovery. At the same time, this may only be a breed specific difference, and not species specific, as Morada Nova breed of sheep was found to recover temperature faster (Arruda & Pant 1984) and the extent of rise in body temperature was lower (Arruda et al. 1984).

Thus, although hairy sheep (like Morada Nova) may be closer to goats than woolly sheep breeds (McFarlane 1968, Singh et al. 1978 and 1980, Rai et al. 1979) in their mechanisms and efficiency of body heat control, some other hairy breeds (like Santa Inês sheep) may be less closer to goats. This may partly be due to the reason that Santa Inês was developed by crossing with some other woolly breeds (Bergamasca, from teperate region, Figueiredo 1980) and hence its mechanisms of homeothermy may still be intermediate to those of tropical goats and woolly sheep. Singh & Acharya (1977) have found significant differences between native and imported breeds of sheep in their mechanisms of heat dissipation.

The overall mean rectal temperature in this experiment had no relation to coat colours of animals which is contrary to the observations of Symington (1960a) who found black animals more heat tolerant and Acharya et al. (1982) who found black or coloured animals less heat tolerant on the basis of their rectal temperature. However, in sheep, black animals had slightly higher increase in the afternoon than white. In goats, there was some evidence of a reverse trend. It was felt that, under the pasturing management used in this experiment, the animals controlled their body temperature within certain limits even though they appeared to have reacted differently to thermal stress on account of their body coat colour as shown by differential effects of coat colours on skin temperatures and respiratory rate. Also, the increase in the afternoon temperatures on different days did not follow the same trend in the two species. Thus, while in sheep the magnitude of increase was greater during the first two days, in goats it was on the last day. This may reflect different threshold levels of environmental temperature that cause thermal load in the two species studied.

The respiratory rate was higher in sheep than in goats and this may be because either it was a species trend (McFarlane 1968) or because their afternoon body temperatures were higher than that of goats and hence they had to have higher rates of respiration. However, the increase in respiratory rate, although still higher in sheep, was comparable in both the species. McFarlane (1968) has reported that at an environmental temperature of 38°C (comparable to afternoon temperatures in the present experiment), Somali blackhead breed of sheep had a respiration rate twice that of goats. Thus different breeds of sheep of similar type may vary greatly in their respiratory response to increased ambiental temperature. Singh & Acharya (1977) and Mali et al. (1982) reported significant differences between native and imported breeds and their crosses in their respiratory rates under heat stress.

The black goats had significantly higher respiratory rate than white goats, but both black and white sheep respired at higher rates. One possible reason may be that the rise in body temperature in the afternoon was higher in sheep and hence the thermal stress on sheep was greater than the limit where colour could have had a differential effect. Hence both black and white sheep laboured to control their afternoon body temperatures within a limit. In goats, on the other hand, the rise in body temperature was lesser than in sheep and perhaps they could tolerate this type of rise better than sheep. Hence, while black goats respired at a higher rate to eliminate extra heat accumulated on account of their body colour, the white goats somehow had a distinct advantage over black goats and maintained their body temperature even by respiring at a much lower rate. Goats are generally considered to be more heat tolerant on account of their larger distribution in tropical and sub-tropical area. But a number of tropical breeds are coloured and seem to be well adapted to hot climate.

In this experiment, only one set of environmental conditions was tested, which does not represent normal variation throughout the year and may not have a positive and significant relationship with productivity of animals. It may, therefore, be useful to further compare the black and white goats for their physiological responses in different seasons of the area and to compare their productivity. Answer to the possible association of colour with adaptability and productivity needs to be obtained at an earlier date to decide whether or not colour should form one of the considerations in planning future breeding programmes for the area.

The midside-skin temperature was measured on both left and right sides of animals nearly over the 10th rib. It was unavoidable to include temperature of hair cover in the measurements although attempts were made to place the probe as close to the skin as possible. Also, the hair tend to lose temperature very quickly and as the animals were in shade when the measurements were taken it may not be important if some hair came in the way of the probe of the thermometer. The skin temperature is lower than the core temperature of the animals because cooling is effected on the surface by evaporative heat loss or by direct radiation. The amount of heat dissipated may depend on the environmental temperature and humidity on one hand and on the surface area of the animal on the other. The amount of hair cover may also influence tolerance to heat (Symington 1960a). Another important factor that may affect skin temperature is the air movement. Bianca (1968) stated that air movement may have heating effect if air temperature was over the body temperature of animals which is rare. However, Priestley (1957) has shown that speed of air movement is an important factor in heat dissipation of sheep in tropical arid regions.

In this experiment, a very large variation occured between morning and afternoon in midside-skin temperature, and it was the single most important factor affecting total variability. Goats had slightly higher skin temperature than sheep in general, but afternoon skin temperature of goats was slightly lower to that of sheep. Thus, goats do seem to have a better heat dissipation mechanism through skin than sheep (Rai et al. 1979). The goats started with relatively higher skin temperature in the morning but net increase was less than in sheep in the afternoon. The black skins had slightly higher temperatures than white which probably indicates their relative reflecting properties. To measure the exact reflecting variation between white and black skins, it may be better to take observations on the animals in the pastures than to bring them in the sheds as was done in this experiment. However, it is very cumbersome to avoid exposure of the probe to sun and measure the skin temperature of animals standing under the sun.

The temperature of the ear-skin was much lower, indicating much lower blood flow (Beakley & Findlay 1955) in the morning. In the afternoon, it was a little lower than the midside-skin temperature but the net increase was much higher than at any other temperature. Beakley & Findlay (1955) have shown that, in calves, the ear temperature can increase by about 18°C with a 5°C variation in environmental temperature. Thus, intermittent vasodilation in rapid response to increase in environmental temperature (less than 30°C in the morning and between 35°C and 37°C in the afternoon in this experiment) may be responsible for sudden increase in ear temperature, although direct exposure to sun can also bring about the increase to some extent. How much important is the dissipation of heat through ear is not known. Some tropically adapted breeds, like Bhuj in Brazil (Shelton & Figueiredo 1981, Figueiredo et al. 1982a), have unusually large ears. In this experiment, there was some evidence of right ear being a little more warmer than left both in the morning and in the afternoon. Although such a difference was significant only in one case, without exception the right ear had higher values. There may be a real tendency for unequal dissipation or blood flow through the two ears, although experimental error can also produce such results. If all animals faced the same direction when measurements were taken, and if the direction of wind was the same during the period of experimentation, such results may occur. However, precautions were taken to avoid such a bias in this experiment.

CONCLUSIONS

1. The earlier studies on goat breed evaluation in northeast Brazil have shown that the native breeds are only colour variants of comparable genotypes and do not differ in their performance. Thus while choosing one of these breeds for further genetic selection programme, some attention to their morphological appearence, may be paid.

2. The colour of sheep and goats under local conditions, on range pastures, may have some relevance to their relative adaptabilities and productivities.

3. The results of this experiment show that colour may play some role in determining the adaptability to heat of goats and white goats seem to adapt better than coloured ones.

4. In spite of relative similarity in their behaviour and appearence, large differences seem to exist between goats and hairy sheep in their relative reactions to environmental variations as reflected by significant interactions between species and other main effects; of the 7 significant interactions obtained 6 had species as one of the components.

5. The goats, in general, seem to be more heat tolerant than sheep as also indicated by the values of a new heat tolerance index.

6. It is necessary to compare Morada Nova and Santa Inês breeds in detail, for their reactions to heat exposure as there are indications that large differences exist between them.

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