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Effect of air temperature and humidity on ingestive behaviour of sheep

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Abstract. Thirty-two Polwarth ewes, of ages up to 1 year, were observed in a climatic chamber (24 to 45° C) for eight periods of 5 h each. The observations were made through a window in the chamber wall. All animals were observed four times, then shorn and observed four times again. The animals were given weighed quantities of water and feed consisting of commercial concentrate plus Rhodes grass (*Chloris gayana*) hay. The water and feed remaining after 5 h of observation were weighed. The following traits were analysed: time eating hay (TEH), time eating concentrate (TEC), time drinking water (TDW), weight of hay eaten (WHE), weight of concentrate eaten (WCE), volume of ingested water (VIW), ruminating time standing up (RTS), ruminating time lying down (RTL), idling time standing up (ITS), and idling time lying down (ITL). Shearing had a significant effect for all traits except ITS. Shearing resulted in higher values for all traits except for ITS and ITL. Ingestion of hay (TEH and WHE) decreased with increased air temperature and humidity, while the ingestion of concentrate (TEC) and WHE) and water (TDW and VIW) increased. Rumination decreased with increased air temperature and humidity, and was higher in shorn than in unshorn sheep.

Key words: Heat stress – Sheep – Behaviour – Feed intake – Water intake

Introduction

Heat stress is generally recognized to decrease the feed intake of ruminants (Baile and Forbes 1974; NRC 1981). Also, changes in the thermal environment induce several specific physiological responses in the digestive system (Christopherson 1985), such as a decrease of blood flow to the rumen (76% under severe stress and 32% under moderate stress), reduction of ruminal motility and reduction of rumination. According to Christopherson (1985), rumination is influenced mainly by the degree of change in the environmental temperature to which the animals are acclimatized, and the absolute air temperature is of secondary importance. Weston (1977) reported that eating and ruminating times of sheep were not altered by heat stress. Similar results were reported by Welch et al. (1982) in heifers. Kennedy et al. (1982) observed increased rumination in cold stressed sheep.

It has been reported that the ratio of rumination time to the time spent by sheep in grazing or in feed intake is about 46% (Arnold and Dudzinski 1978). Field observations at Jaboticabal, Brazil (Fares et al. 1987) indicated that rumination time during daylight was about 11% of the total grazing time. The average idling time spent lying down during summer is higher in sheep (83%) than in cattle (67%) according to Arnold and Dudzinski (1978). These authors found that, in cattle, increases of air temperature from 16 to 18° C resulted in a decrease of idling time lying down and an increase of idling time standing up. Increased air temperature also affected the direct intake of water in sheep, but it was also noted that green forage may supply most of the water requirements of sheep even in warm environments.

Measures to predict the interaction of temperature and feed intake in sheep are limited, mainly because the vast majority of sheep are kept under extensive grazing. Few data exist for the ingestive behaviour of sheep under severe heat stress. Moreover, the results of two climatic chamber studies (Bhattacharya and Hussain 1974; Bhattacharya and Uwayjan 1975) conflict in some aspects. The objective of the present study was to determine the behaviour of Polwarth sheep with respect to the ingestion of food and water under high environmental temperatures.

Materials and methods

Thirty-two Polwarth ewes, of ages up to 1 year, were observed in a climatic chamber under varying conditions of air temperature

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(24 to 45° C) and humidity (1.0 to 3.5 kPa vapour pressure). The air temperature and humidity were monitored continuously inside the chamber. Eight sheep were tested in each session of observations with one animal per box measuring 1.5 × 1.0 m. Each animal was observed eight times under different environmental conditions, four times unshorn and four times shorn. All observations, conducted in the period of 27 April to 26 June, 1989, were made through a window in the chamber wall between 1000 and 1500 h.

Animals entered the chamber at 0900 h, 1 h after receiving 10 l of water, 1 kg of commercial concentrate and 0.5 kg of ground Rhodes grass (*Chloris gayana*) hay, served in separate holders. The animals were released from the chamber at 1500 h, at which time the remaining water and feed were measured to estimate the ingested amounts.

The following variables were measured: time eating hay, TEH (s); time eating concentrate, TEC (s); time drinking water, TDW (s); weight of hay eaten WHE (g); weight of concentrate eaten, WCE (g); volume of ingested water, VIW (ml); ruminating time standing up, RTS (s); ruminating time lying down, RTL (s); idling time standing up, ITS (s); and idling time lying down, ITL (s).

Variations in the traits TEH, TEC and TDW were continuously measured for each individual by means of a stop-watch. The recording of RTS, RTL, ITS, and ITL on the other hand was based on an instantaneous sampling technique described by Martin and Bateson (1986), in which the activities were recorded at 5 min intervals.

The data were analysed by the method of least squares (Harvey 1960), according to the following model:

$$Y_{ijklm} = u + a_i + c_j + t_k + h_l + e_{ijklm},$$

where: Y_{ijklm} is the m^{th} observation of the i^{th} animal ($i = 1, \ldots, 32$), of the j^{th} wool coat condition (shorn or unshorn), under the k^{th} environmental temperature level ($k = 1, \ldots, 7$) and l^{th} air humidity level; u is the overall mean, and e_{ijklm} is the random error.

Results and discussion

Sheep tended to present individual patterns of feed and water ingestion under the conditions prevailing in the chamber. Analyses of variance (Table 1) showed that individuality among animals was significant at the 1% level for TEH, TEC, TDW, WHE, WCE, VIW, ITL; and at the 5% level for RTS and ITS. Shearing was a significant factor also for the above cited traits except ITS, and shorn animals presented higher values for these traits except ITS and ITL, which showed lower values (Table 2). Hay ingestion (time and amount) tended to decrease with the increase in air temperature and air humidity, while ingestion of concentrate (time and amount) tended to increase. Table 3 shows significant negative correlations of TEH and WHE with air temperature and air humidity. For the air temperature the respective coefficients were higher for shorn than unshorn ewes, while for air humidity they were lower for shorn ewes.

Mendes et al. (1976) observed sheep of the Bergamascia breed under two levels of air temperature (22 to 25° C and 32 to 35° C respectively); a decrease was recorded in the dry matter intake (from 66.3 to 59.9 $g \cdot kg^{-0.75}$) and an increase in ingestion of water (from 2.13 to 4.04 kg per kg of dry matter intake). In the literature (Bhattacharya and Hussain 1974; Forbes 1986), it is reported that ruminants tend to reduce ingestion of roughage rations in relation to that of concentrates when they are under heat stress. Conrad (1985) reviewed this subject and suggested that forage quality has a direct effect on digestibility, by which a greater digestible energy fraction in high-quality forage induces more feed intake per unit of body weight.

Bhattacharya and Hussain (1974) carried out an experiment with Awasi sheep receiving different proportions of roughage to concentrate under low (11 to 22° C) and high (27 to 32° C) temperatures. They observed that when this proportion was high (75:25), voluntary feed intake was maximum under low temperatures and minimum under high temperatures (879 and 447 g, respectively). When the proportion was inverted (25:75), the animals decreased ingestion to 758 g under low temperature and increased it to 652 g under high temperatures. The authors concluded that the effect of high temperature on feed intake was negative and became more pronounced when the diet had a high fibre content.

On the other hand, Bhattacharya and Uwayjan (1975), maintained 10 wethers of Awasi breed under low (8.6 to 25.3° C) temperatures and found no significant effect on feed intake. However, at higher air tempera-

Table 1. Mean squares of 10 traits measured in 32 Polwarth ewes exposed repeatedly to variable levels of air temperature and humidity

Source	Subjects	Coat condition	Air temperature	Air humidity	Error
Degrees freedom	31	1	6	6	179
Traits:					
Time eating hay	7807910**	39351378**	39663974**	41821049**	1841864
Time eating concentrate	593973**	3058224**	1238283**	1025729**	143766
Time drinking water	10197**	17253**	23883**	19059**	1535
Weight of hay eaten	19972**	100107**	37063**	51943**	4114
Weight of concentrate eaten	15045**	85885**	13048**	8594*	3807
Volume of ingested water	162064**	8331964**	8556039**	5122450**	257273
Idling time standing up	10845908*	17231692	15418525*	14468996*	6069748
Idling time lying down	25754821**	45457625**	238827664**	170445679**	5254466
Ruminating time standing up	756363*	1837582*	4042963**	3054275**	429042
Ruminating time lying down	1275870	5704196*	47545217**	27160886**	1400942

* $P<0.05$; ** $P<0.01$

Table 2. Least squares means of 10 traits measured repeatedly in 32 Polwarth ewes exposed to variable levels of air temperature and humidity: time eating hay (TEH), time eating concentrate (TEC), time drinking water (TDW), weight of hay eaten (WHE), weight of concentrate eaten (WCE), volume of ingested water (VIW), idling time standing up (ITS), idling time lying down (ITL), ruminating time standing up (RTS), and ruminating time lying down (RTL)

Factor Unit	*n*	TEH s	TEC s	TDW s	WHE g	WCE g	VIW ml	ITS s	ITL s	RTS s	RTL s
Overal mean:											
u	224	2581.4	1030.1	42.0	120.1	173.2	817.6	3767.7	8311.6	413.2	1402.4
Standard error		±131.3	±31.1	±3.7	±5.8	±4.9	±52.3	±163.1	±257.9	±50.8	±110.7
Coat condition:											
Unshorn	96	2097.4	895.2	31.9	95.7	150.6	594.9	4087.9	8831.8	308.6	1218.1
Shorn	128	2944.3	1131.3	49.6	138.4	190.2	984.6	3527.5	7921.5	491.6	1540.6
Air temperature (° C):											
<24	20	3995.0	927.2	6.3	167.4	150.0	180.1	4659.7	5053.5	769.8	2588.6
24–28	60	3588.9	805.7	15.9	136.9	163.3	371.0	3550.8	6240.0	758.2	2564.4
28–32	32	2432.5	1276.9	56.8	88.8	187.5	550.5	3308.7	5892.3	677.2	2400.7
32–36	8	2447.9	961.3	21.9	119.6	150.0	556.9	3569.5	10541.5	345.5	112.5
36–40	28	3076.6	907.0	35.0	166.4	150.0	972.1	3940.9	9335.6	76.3	600.1
40–44	64	1431.9	1186.8	67.4	93.3	187.5	1434.8	3452.9	11620.0	75.0	171.6
>44	12	648.6	1163.3	86.7	76.0	216.7	1346.7	5995.2	9031.3	25.0	250.0
Air humidity (kPa):											
<1.8	16	4394.6	960.6	13.4	186.0	150.0	388.8	4608.3	4723.1	1053.1	2246.9
1.8–2.1	32	3437.0	899.7	21.8	145.7	150.0	434.4	3346.7	7203.7	632.6	2456.4
2.1–2.4	64	3310.7	865.8	20.5	136.6	168.8	558.2	3553.3	7394.8	523.0	1886.4
2.4–2.7	36	1843.6	1306.4	67.2	85.7	194.4	809.6	4203.8	6753.8	476.6	1621.1
2.7–3.0	32	2451.0	1004.1	57.7	143.3	175.0	1196.6	3427.8	10524.7	66.8	443.6
3.0–3.3	20	1158.8	1204.2	60.2	81.0	190.0	1543.0	5189.9	10206.9	90.0	90.0
>3.3	24	752.8	1163.8	71.8	51.4	183.3	1028.3	2953.8	12432.8	37.5	187.5

Table 3. Correlation coefficients between air temperature and air humidity for 10 traits measured in Polwarth ewes

Trait	Unshorn sheep		Shorn sheep	
	Temperature	humidity	Temperature	humidity
Time eating hay	−0.435**	−0.562**	−0.524**	−0.494**
Time eating concentrate	0.167	0.130	0.235**	0.369**
Time drinking water	0.334**	0.326**	0.411**	0.401**
Weight of hay eaten	−0.166	−0.383**	−0.245**	−0.386**
Weight of concentrate eaten	0.085	0.017	0.208*	0.382**
Volume of ingested water	0.485**	0.362**	0.686**	0.526**
Idling time standing up	−0.180	−0.248*	0.134	0.039
Idling time lying down	0.692**	0.602**	0.581**	0.427**
Ruminating time standing up	−0.365**	−0.245*	−0.454**	0.348**
Ruminating time lying down	−0.613**	−0.407**	−0.691**	0.498**

* $P<0.05$; ** $P<0.01$

tures (21.0 to 32.5° C) an increase of air temperature significantly decreased the feed intake for all rations (25, 50 and 75% roughage content). The depression was highest (20%) in a 25% roughage ration.

In the present study there was a reduction in the rate of ingestion of hay and an increase in the ingestion of concentrate during exposure of shorn sheep to high temperatures. Furthermore, there were significant correlations between air temperature and TEC and WCE only for the shorn animals (Table 3). Responses to air humidity were similar to but more pronounced than those for temperature. This may be explained by a decrease in evaporative thermolysis with increasing air humidity.

Table 4. Per cent of time showing behavioural traits by 32 Polwarth ewes exposed to heat stress before and after shearing

Behaviour	Unshorn sheep	Shorn sheep
Idling	74.0	65.0
Rumination	8.7	11.6
Feed ingestion	17.1	23.1
Water ingestion	0.2	0.3
Total	100.0	100.0

Table 5. Correlation coefficients for 10 traits measured in 32 Polwarth ewes exposed repeatedly to variable levels of air temperature and humidity

Traits[a]	TEH	TEC	TDW	WHE	WCE	VIW	ITS	ITL	RTS	RTL
TEH	1	−0.185*	−0.112	0.780**	−0.121	−0.051	−0.019	−0.602**	−0.168*	0.314**
TEC		1	0.204**	−0.147*	0.738**	0.177*	−0.236**	0.101	0.001	−0.042
TDW			1	−0.010	0.114	0.623**	0.043	0.085	−0.104	−0.264
WHE				1	−0.153*	0.138*	−0.040	−0.414**	0.071	0.153*
WCE					1	0.138*	−0.195**	0.052	−0.051	−0.072
VIW						1	0.083	0.203**	−0.257**	−0.372**
ITS							1	−0.502**	0.044	−0.208**
ITL								1	−0.481**	−0.497**
RTS									1	0.258**
RTL										1

[a] The investigated traits are as defined in Table 2

* $P<0.05$; ** $P<0.01$

Shorn animals presented correlations of 0.369 and 0.382 between air humidity and TEC and WEC respectively. For unshorn animals the corresponding values were 0.130 and 0.017. Unshorn sheep are affected less evidently by variations in the air humidity since the wool presents a barrier to cutaneous evaporation. Although the evaporation is higher in shorn animals, the effective cooling by this mechanism may be impaired by increased air humidity. Higher cutaneous evaporation in shorn sheep was reported by Klemm (1962) and Thwaites (1985).

Water consumption was higher on average in the shorn sheep (984.6 ml) than in the unshorn (594.9 ml); but the water intake of unshorn sheep was affected less by variations in air temperature and humidity (Tables 3 and 4). The intake of hay and concentrate had little effect on water intake, as shown by the low values of the correlations between the variables associated with feed intake (TEH, TEC, WHE and WCE) and those associated with water intake (TDW and VIW) (Table 5).

Postural behaviour differed significantly among shorn and unshorn animals, except for ITS. Unshorn ewes spent more time idling (4087.9 s for ITS and 8831.8 s for ITL on average) and less time ruminating (308.6 s for RTS and 1218.1 s for RTL on average) compared with shorn ewes (3527.5 s for ITS and 7921.5 s for ITL, 491.6 s for RTS and 1540.6 s for RTL). Ruminating time (RTS and RTL) decreased with the increase of air temperature and humidity (Table 2). Shorn animals spent more time ruminating than unshorn, with both spending more time lying down than standing up (76% for shorn and 80% for unshorn). Shorn animals spent more time eating food and drinking water (23.1 and 0.3% respectively) and ruminating (11.6%) than unshorn ones (17.1%, 0.2% and 8.7%, respectively) (Table 4). These differences were significant in absolute values (Table 1). Air temperature and humidity affected all measures of postural behaviour significantly (Table 1).

Our results correspond with those in the literature, for a negative effect of heat stress on the ingestion of food, and for a positive effect on the ingestion of water. No reference was found for the interaction of heat stress and shearing with feed intake.

The following conclusions were drawn from the analyses:

(1) Shorn sheep under heat stress ingested significantly less roughage and more concentrate. Unshorn sheep under heat stress also ingested less roughage but the decrease was of a lower magnitude than in the shorn animals. Shearing under heat stress had no effect on the ingestion of concentrate.

(2) Water consumption was significantly higher in shorn than in unshorn sheep during heat stress.

(3) Rumination was higher in shorn than in unshorn sheep, probably due to higher ingestion of fibre.

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