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EFFECT OF HEAT STRESS ON FEED INTAKE, RUMEN FERMENTATION AND WATER TURNOVER IN RELATION TO HEAT TOLERANCE RESPONSE BY SHEEP

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SUMMARY

Five mature male sheep were housed in controlled temperature chamber under 18°C or 35°C. Animal were fed barley grains and Berseem hay ad lib. Sheep under heat stress decreased their concentrate intake by about 13% without change in roughage intake. Roughage:concentrate ratio was higher under hot condition. Insignificant increase in DM, OM, CP, CF and NFE was observed under heat stress. Heat stress increased water intake by about 50% but water loss in feces was decreased by about 25% and by 40% in urine. Insensible water loss under 35°C was two times more than that under 18°C. Animal under hot condition showed higher ($P<.05$) rumen volume, rumen temperature and molar proportion of propionate but lower ($P<0.01$) buffering capacity, protozoa count and total VFA's concentrations and ($P<.05$) concentrations of ammonia-N, butyrate molar proportions and acetate: propionate ratio. Ruminal pH and acetate molar proportions had not significantly affected by heat stress. Body temperature and respiration rate increased ($P<.01$) but pulse rate showed little response due to heat stress.

Keywords: Sheep, heat stress, feed intake, digestibility, water turnover, rumen fermentation

INTRODUCTION

In temperate regions episodic thermal stress may pose serious problems for ruminants in comparison with the less heat sensitive breeds, because animals have not adapted physiologically to these conditions. However, global climatic changes due to increasing atmospheric carbon dioxide content (United State Department of Energy, 1990) could result in so-called "Greenhouse Effect" widening the torrid zone, impacting severely on intensively managed food producing animals (Beede and Collier, 1986). Consequently, three basic management strategies have been suggested attenuating effects of thermal stress:
1) physical modification of the environment, such as reducing incoming radiation via shade, thus reducing the heat load on the animals (Buffington *et al*. 1983); 2) genetic development of less heat-sensitive breeds (Finch, 1986) and 3) improved nutritional management schemes. A lot of research works have been conducted to study morphological, anatomical and physiological merits of subtropical breeds for adaptation to hot condition, over that of temperate breeds. However, the role of rumen in this adaptation is not given sufficient concern.

The present study was carried out to study the response of rumen along with thermo-cardio respiratory adaptive response of sheep exposed to heat stress.

MATERIALS AND METHODS

Five mature male Rahmani x Ossimi sheep fitted with permanent rumen cannula were individually housed in metabolism crates in controlled heat temperature chamber under ambient temperature of 18°C or 35°C for 31 days for each environmental temperature. Preliminary period lasted 21 days and 7 day-collection period to determine nutrient digestibilities. Rumen fluid sampling and estimation of rumen fluid volume were carried out within the following three days.

Animals were fed *ad. lib.* on surplus of Berseem hay and barley grains. Feeds were offered to insure a residual not less than 10% of the offered. Water was offered *ad. lib.* twice a day at 11:00 and 17:00 and daily water consumption was recorded.

Chemical composition of feed and feces was determined according to A.O.A.C. (1975).

Rumen samples were collected at 2, 4, 6, 8 and 24 hrs. post- feeding to determine the following rumen fluid traits at each time according to the mentioned references: Ammonia nitrogen concentrations (Conway 1962), concentration of total volatile fatty acids (Kromann et al. 1967), molar proportions of volatile fatty acids (Erwin et al., 1961), buffering capacity (Nicholson et al., 1963), protozoa count (El-Saifi, 1969) and rumen fluid volume was determined using Lithium sulphate (Mangan and Wright 1968). Internal rumen temperature was measured by inserting thermometer through rumen cannula in the rumen content. Ruminal fluid pH was determined soon after sample collection.

Data of rumen parameters for each trait were pooled for the sampling time because of ad libitum feeding.

Heat tolerance responses were daily estimated by measuring body temperature, pulse and respiration rates twice at 8:00 and 15:00 hr.

Difference between the two treatment means was tested with Student-T test (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Chemical composition and nutrient digestibilities are shown in Table 1. Under heat stress condition, Sheep digested DM, OM, CP, CF and NFE slightly higher than under 18°C. The results of Miller et al. (1974) and Lippke (1975) indicated a relationship between the reduction in thyroxine in heat stressed whethers and steers and low rate of passage and/or rate of digestion which results in higher fiber and dry matter digestibilities.

Sheep under 35°C consumed insignificance less concentrate and total DM than sheep under 18°C. Animals reduced their concentrate intake by about 13% under hot conditions without change in roughage intake maintaining higher roughage percentage (25% vs 17.6%) in their rations by ad. lib. feeding (Table 2). This little reduction in concentrate (barley) does not seem to be the way to reduce metabolic heat production by the local breeds of sheep which are adapted to the hot environment. In comparison with the controlled feed intake for maintenance in the first part of this study (Murad et al. 1994), sheep were able to increase their feed intake by ad. lib. feeding three time more than their maintenance requirements even under heat stress condition. This point could be an advantage for the endogenous breed over the temperate zone-breeds which are reported that their dry matter intake drastically decreased and consequently their productivity under hot environment (Beede and Collier 1986; Knapp and Grummer 1991).

Table 1. Chemical composition, nutrient digestibility and nutritive value of diets fed to sheep ad. lib. under 18°C and 35°C environmental temperature

Item	Ambient Temperature	
	18 °C	35 °C
Dry matter, %	92.29	92.23
Dry matter composition,%		
Organic matter (OM)	95.07	94.80
Crude protein (CP)	13.87	14.12
Ether extract (EE)	3.75	3.69
Crude fiber (CF)	9.98	10.88
N-free extract (NFE)	67.47	66.11
Ash	4.93	5.20
Digestibility,%		
DM	74.2+1.5	78.2+2.4
OM	77.1+1.4	79.6+2.2
CP	70.6+2.9	74.4+3.6
EE	76.3+1.5	64.1+4.4
CF	35.5+6.7	40.4+7.9
NFE	84.6+1.8	87.9+1.2
Nutritive value, %		
TDN	76.9+1.3	78.4+2.2
DCP	9.8+0.5	10.5+0.7

The digestibility of EE was ($P<.05$) different.

In this connection, genetic improvement of less heat-sensitive breeds has been suggested by Finch (1986) as one of three basic management strategies for attenuating effects of thermal stress including the physical modification of the environment, such as reducing incoming radiation via shade (Buffington et al., 1983) and improving nutritional management schemes (Beede and Collier, 1986).

Table 2. Effect of heat stress on voluntary dry matter intake and water balance by sheep fed ad. lib.

Item	Ambient Temperature	
	18 °C	35 °C
Body weight		
Kg	57.1 + 2.5	60.7 + 3.6
$Kg/W^{0.75}$	20.8 + 0.6	21.8 + 0.2
DM intake, $g/KgW^{0.75}$		
Barley	77.9 + 3.6	67.4 + 4.3
hay	16.6 + 3.7	16.9 + 1.3
Total	94.5 + 3.8	84.3 + 3.7
Roughage,%	17.6	25.1
Water intake (WI)		
ml/head/day	4118^{b} + 21	6129^{a} + 7
$ml/KgW^{0.75}$	198^{b} + 10	282^{a} + 9
Water output(WO), ml/head/day		
Feces	1091^{a} + 68	835^{b} + 53
Urine	742^{e} + 58	451^{f} + 43
Total	1833^{a} + 36	1286^{b} + 66
Insensible water loss (WI-WO)		
ml/day	2285^{b} +243	4843^{a} + 66
$ml/day^{0.75}$	110^{b} + 12	223^{a} + 3

a, b Means on the same line bearing different superscripts differ (P<.01)

e, f Means on the same line bearing different superscripts differ (P<.05)

Drastic effect of ambient temperature on water input-output relationship was observed since sheep under 35°C consumed ($P<0.01$) more water and required ($P<0.01$) more water per g DM intake. Animals excreted less water in ($P<0.01$) feces and ($P<0.05$) in urine. Insensible water loss (WI-WO) was extremely higher for sheep under 35°C reaching 80% of water input compared with 55% for sheep under 18°C (Table 2). These results might confirm again that altering water metabolism by local sheep under hot condition to regulate body temperature is with an importance more than that by decreasing feed intake. Increasing water intake was reported by Beede and Collier (1986) as a major response to thermal stress since consumed water directly cools the reticulorumen and serves as the primary vehicle for heat transfer and dissipation through sweating and panting. Moreover, McDowell (1972) found that water consumption of lactating cows increased by 29% at 30°C; fecal water loss declined by 33% but loss of water via urine, skin and respiratory evaporation increased 15, 59 and 50%, respectively.

Rumen parameters in Table 3 showed an increase ($P<0.05$) in rumen volume, depression in protozoa count ($P<0.01$), concentrations of ammonia nitrogen ($P<0.05$) and total VFA's ($P<0.01$) was observed by increasing ambient temperature. Moreover, under hot condition, molar proportion of propionate increased ($P<0.05$), butyrate decreased ($P<0.05$) and slight decrease in acetate was observed. These changes in molar proportion of VFA's reflected on lower A/P ratio. These results indicate that the change in the molar proportions of VFA's of sheep fed high concentrate diets under high ambient temperature is largely due to the increase in propionate and decrease in butyrate not to the decrease in acetate as stated by Schneider _et al_. (1988). Ruminal pH was not affected by high ambient temperature although buffering capacity was the most affected measurement in the rumen parameter. Increasing ambient temperature increased ($P<0.05$) rumen temperature which could be a reason for the decrease in protozoa count. Brody _et al_. (1955) had suggested that ambient temperature may affect rumen organisms. This result was in agreement with those found by Collier _et al_. (1982); Niles _et al_. (1980) and Gengler _et al_. (1970).

Table 3. Effect of heat stress on rumen fluid parameters of sheep <u>ad</u>. <u>lib</u>.

Parameter	Ambient Temperature	
	18 °C	35 °C
Rumen fluid volume, ml.	4.03^{f} + 0.43	5.25^{e} + 0.71
Protozoa count $(10)^6$	2.97^{a} + 0.78	0.83^{b} + 0.19
ammonia-N, mg/100 ml	26.1^{e} + 1.04	20.3^{f} + 2.37
VFA's m.eq./100 ml	26.5^{a} + 2.08	14.7^{b} + 1.15
Acetate, %	33.3 + 1.46	30.5 + 2.61
Propionate, %	31.9 f + 2.19	41.0^{e} + 3.35
Butyrate, %	34.8^{f} + 3.05	28.5^{f} + 5.83
A/P ratio	1.04^{e} + 0.07	0.74^{f} + 0.08
pH	5.67 + 0.07	5.62 + 0.13
Buffering capacity	84.3^{a} + 2.11	48.3^{b} + 4.14
Temperature	39.22^{a} + 0.42	39.68^{e} + 0.38

$^{a, b}$ Means on the same line bearing different superscripts differ (P<.01)

$^{e, f}$ Means on the same line bearing different superscripts differ (P<.05)

Increasing ambient temperature from 18°C to 35°C increased (P<0.01) rectal temperature and respiration rate measured at 8.00 hr or 15 hr.

However, the effect on pulse rate was limited. Since, almost no change at 15.00 hr and small increase were observed at 8.00 hr (Table 4).

Similar responses to heat stress were found by Knapp and Grummer (1991) Gangwar (1988) and Bunting <u>et al</u>. (1992). It was evident from the present study compared with the finding of the first part (Murad <u>et al.</u>, 1994) that local sheep were not able to maintain their body temperature when <u>ad lib</u>. feeding system was followed under heat stress.

It could be concluded that the less heat-sensitive breeds of sheep like Rahmani sheep could alleviate heat stress by modification in water metabolism severely than by reduction in feed intake.

Table 4. Thermo-cardio-respiratory response of sheep fed <u>ad</u>. <u>lib</u>. under 18°C and 35° C environmental temperature

Parameter	Ambient Temperature	
	18°C	35 °C
Body temperature		
at 8.00 hr	38.72^{b} + 0.04	39.07^{a} + 0.03
at 15.00 hr	38.83^{b} + 0.03	39.11^{a} + 0.03
Pulse rate		
at 8.00 hr	68.84^{e} + 1.13	73.13^{f} + 1.36
at 15.00 hr	71.63 + 0.74	71.33 + 0.76
Respiration rate		
at 8.00 hr	17.30^{b} + 1.25	67.52^{a} + 3.23
at 15.00 hr	18.90^{b} + 0.29	70.01^{a} + 3.00

a, b Means on the same line bearing different superscripts differ (P<0.01)

e, f Means on the same line bearing different superscripts differ (P<0.05)

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تأثير الإجهاد الحرارى على المأكول من الغذاء وتخمرات الكرش وتمثيل الماء وعلاقتها بمقاييس التحمل الحرارى فى الأغنام

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أجريت هذه الدراسة على خمسة كباش بالغة وضعت فى غرف تحكم حرارى تحت درجة حرارة ١٨°م أو ٣٥°م وغذيت لحد الشبع على حبوب الشعير ودريس البرسيم بهدف دراسة تأثير الإجهاد الحرارى على المأكول الإختيارى وتخمرات الكرش وتمثيل الماء ومقاييس التحمل الحرارى.
وتلخصت النتائج فيما يأتى :
– الأغنام المعرضة للإجهاد الحرارى قللت من المأكول الإختيارى من المادة المركزة (الشعير) بحوالى ١٣٪ ولم تغير المأكول من المادة الخشنة (الدريس) مما ادى إلى زيادة نسبة المركز إلى الخشن فى عليقتها .
– حدثت زيادة غير معنوية فى معاملات هضم المركبات الغذائية ما عدا مستخلص الأثير تحت ظروف الإجهاد الحرارى .
– زادت كمية ماء الشرب بنسبة ٥٠٪ بينما أنخفض الماء الخارج فى الروث بنسبة ٢٥٪ والماء الخارج فى البول بنسبة ٤٠٪ وتضاعفت كمية الماء الخارج فى العرق والتنفس فى الأغنام المعرضة للإجهاد الحرارى تحت درجة حرارة ٣٥°م .
– أدت ظروف الإجهاد الحرارى إلى زيادة فى حجم سوائل الكرش ودرجة حرارة محتوياته ونسبة البروبيونات وأيضا إلى إنخفاض فى القدرة التنظيمية وتركيز كل من الأمونيا والأحماض الطيارة الكلية وعدد البروتوزوا ولم تتأثر كل من درجة حموضة سائل الكرش ونسبة الأسيتات إلى البروبيونات بزيادة درجة حرارة الجو .
– لوحظت زيادة فى درجة حرارة الجسم ومعدل التنفس بدرجة أعلى من الزيادة فى معدل نبض الأغنام المعرضة لدرجة الحرارة العالية .