The 3rd ISTAP, Faculty of Animal Science, Gadjah Mada University, 2002 *ISBN : 979 – 97243 – 2 - 5*

FEED DIGESTIBILITY AND MICROBIAL NITROGEN PRODUCTION IN PAIR-FED LAMBS AT 20°C AND 50°/42°C WHEN WATER INTAKE WAS RESTRICTED AT THE HIGHER TEMPERATURE

E. Rianto[1], C.J. Thwaites[2] and J.V. Nolan[2]

Abstract

This experiment was conducted to investigate the effect of high temperature on feed digestibility and microbial nitrogen production (MNP) in lambs when feed intake (FI) and water intake (WI) were both controlled so as to be similar to those at thermo neutrality. Eight lambs were allocated into a pair feeding experiment. They were fed oaten chaff (1.67% N) and watered at similar levels, irrespective of temperature. Two ambient temperature treatments were applied (20°C constant, or 50°C during the day and 42°C at night). Lambs at 20°C were given a restricted feed allocation that was determined by the unrestricted FI of their pair-mates at 50°/42°C on the previous day, and water *ad libitum*, while lambs at 50°/42°C were watered at the minimum level (2.8 l/d) that allowed dry matter (DM) intake to be maintained at 20°C levels. DM and N digestibility at 20°C (66.9 and 67.7 % respectively) were higher than at 50°/42°C (62.9 and 64.2 % respectively), but temperature did not affect MNP and efficiency of MNP (EMNP), means of 4.8 g/d and 12.5 g/kg digestible organic matter intake respectively. Both respiration rate (RR) and rectal temperature (RT) at 50°/42°C (126 breaths/min and 40.2°C, respectively) were higher than at 20°C (40 breaths/min and 38.6°C, respectively). It was concluded that in lambs at 50°/42°C, which had the same DM intake and a higher WI than at 20°C, DM digestibility was increased while MNP and EMNP were not influenced.

Key words: Lamb, Ambient temperature, Water restriction, Pair feeding, Feed digestibility, Microbial nitrogen production.

Introduction

The result of an experiment by Rianto *et al.* (2002) showed that the DMD, OMD and ND were greater at high compared to low ambient temperature. However, it cannot be concluded yet whether those differences resulted directly from temperature or were an indirect effect mediated via FI, as at high temperature the FI was depressed by 28% (from 1080 g/d at 20°C to 776 g/d at 50°/42°C).

[1] Faculty of Animal Agriculture Diponegoro University, Semarang.

[2] Department of Animal Science, the University of New England, Armidale.

The results of the experiment by Rianto *et al.* (2002) also indicated that while DMI was decreased at high temperature, the EMNP was not influenced when WI was the same at both temperatures. This suggests that DMI is not the only factor affecting EMNP in lambs (Chen *et al.*, 1992b; Djouvinov and Todorov, 1994), but that rumen LOR may also be involved (Hungate, 1966; Van Soest, 1994). Rumen LOR has been shown to be influenced by WI (Harrison *et al*, 1975).

The current experiment was thus carried out to determine the effects of high ambient temperature on feed digestibility and utilisation in lambs when DMI and WI were controlled during exposure to high temperature so as to be as similar as possible (see 6.2.1) at both temperatures. The plan was for lambs at 20°C to be pair-fed to those at 50°/42°C, and it was thus anticipated that DMI at 20°C in the current experiment would be lower than recorded in the experiment of Rianto *et al.* (2002), when feeding was *ad libitum*. Accordingly WI at 20°C was also anticipated to be lower than recorded in experiment Rianto *et al.* (2002), i.e. 3.1 l/d; a value which was itself much lower than the *ad libitum* WI of lambs at 50°/42°C (3; 7.5 l/d). The choice needed to be made, therefore, between maintaining DMI relatively constant at both temperatures and accepting some variation in WI, or the reverse. WI had been kept constant at both temperatures in the experiment of Rianto *et al.* (2002), so the decision for the current experiment was to maintain DMI constant and to accept any small variations that occurred in WI. To do the reverse ran the very real risk that an inadequate WI at 50°/42°C would have led to an uncontrolled down turn in DMI and thus difficulties in interpreting the results.

The hypotheses to be tested were:

a) That at the same DMI, DMD would be higher at 50°/42°C that at 20°C
b) That anticipating higher WI, MNP and EMNP would be higher at 50°/42°C that at 20°C.

Materials and Methods

Animals and Experimental Design

Eight lambs were allocated to a pair-feeding experiment. They were kept in metabolic crates, 4 in a room at 20°C and 50% RH and the other 4 in a room at 50°/42°C and 40% RH. To establish the level of restriction of WI at 50°/42°C that would allow comparable DMIs to occur at both temperatures, the WI of lambs at 50°/42°C on d 4 was restricted to that of lambs at 20°C (1900 $\pm$ 142 ml/d). The immediate response on d 4 was a decline in DMI to 472 $\pm$ 77 g/d; a figure that was calculated to provide only about 71% of the energy requirement for maintenance of lambs of this BW (SCARM, 1990).

On d 5 WI, at 50°/42°C was increased to 1.5 times that of controls (a mean of 2843 ml/d) and DMI was then maintained at 581 $\pm$ 91 g/d (= 91 % of maintenance). As the University of New England Animal Care and Ethic Committee rules limited

the time in metabolism crates at 50°/42°C to 8 days, these levels of restricted WI and DMI were adopted for the current experiment that ran from d 6 to d 11. The 4 lambs at 20°C were pair-fed to levels recorded for their counterparts the previous day at 50°/42°C, and their WI was *ad libitum*.

Procedures

The lambs at both temperatures were fed the same diet, i.e. oaten chaff, which was available when this experiment began. The feed given to and refused by the animals was analysed for DM, OM, and N as previously described. The procedures to estimate feed digestibility, MNP and EMNP were as reported by Rianto *et al.* (2001)

Table 1.The nutrient content of the diet used

Component	Content (%)
DM	90.5
OM	92.8
N	1.67

DM = dry matter; OM = organic matter; N = nitrogen

Results and Discussion

The experimental procedures adopted resulted in non-significant differences in DMI and OMI between temperatures, but a significantly higher WI at 50°/42°C than at 20°C (Table 2). Significant differences ($P<0.05$) in DMD and ND were recorded, with higher values at 20°C than at 50°/42°C (Table 3); MNP and EMNP were not significantly affected ($P>0.05$) by temperature (Table 3). The RR ($P<0.01$) and RT ($P<0.001$) of lambs at 50°/42°C was significantly higher than at 20°C (Table 3). The volume of urine excreted was also higher at 20°C than at 50°/42°C; 675 vs. 219 ml/lamb/d respectively ($P<0.001$).

Table 2.Feed and water intakes

Parameter	Ambient temperature		Significance of difference
	20°C	50/42°C	
WI (ml/d)	2036 ± 403	2843 ± 262	*
DMI (g/d)	600 ± 87	581 ± 91	ns
OMI (g/d)	556 ± 82	539 ± 89	ns

WI = water intake; DMI = dry matter intake; OMI = organic matter intake
ns = $P>0.05$; * = $P<0.05$

Table 3.The effects of ambient temperature on feed digestibility, digestible organic matter intake, estimated net microbial nitrogen production and its efficiency, respiration rate, rectal temperature and urine excretion in lambs

Parameter	Ambient temperature		Significance of difference
	20°C	50/42°C	
DMD (%)	66.9 ± 2.49	62.9 ± 1.90	*
ND (%)	67.7 ± 1.0	64.2 ± 2.00	*
DOMI (g/d)	392 ± 43.0	348 ± 51.0	ns
MNP (g/d)	5.8 ± 1.45	3.9 ± 0.83	ns
EMNP (g MN/kg DOMI)	14.0 ± 2.84	11.0 ± 1.33	ns
RR (breaths/min)	40.0 ± 5.50	126.0 ± 14.0	**
RT (°C)	38.6 ± 0.15	40.2 ± 0.10	***
Urine excretion (ml/d)	675 ± 33.6	219 ± 11.7	***

DMD = dry matter digestibility; ND = nitrogen digestibility; DOMI = digestible organic matter intake; MNP = net microbial nitrogen production; EMNP = efficiency of net microbial nitrogen production; RR = respiration rate, RT = rectal temperature
ns = P>0.05; * = P<0.05; ** = P<0.01; *** = P<0.001

The results of the current experiment indicate that the DMD and ND in lambs at 50°/42°C were actually lower than at 20°C, when WI at 50°/42°C was restricted to a level near to that of lambs at 20°C (2.8 vs. 2.0 l/d respectively). This is the first reported occasion on which FI and WI effects have been separated from the general ones of heat stress. Any conflict between this result and earlier reports in the literature (Graham *et al.*, 1959; Kotb and Pfander, 1965; McDowell *et al.*, 1969; Moose *et al.*, 1969; Bhattacharya and Hussain, 1974; Christopherson, 1976; Conrad, 1985; Rianto *et al.*, 2002) can be explained by the combined effects of the changes in FI and WI that are likely to occur under uncontrolled conditions at high temperature. Thus the differences in the results of the current experiments and that of Rianto *et al.* (2002) may be explained by the fact that in the experiment of Rianto *et al.* (2002) FI at 50°/42°C was much lower than at 20°C (776 vs. 1180 g DM/d respectively), while in the current experiment FI was similar at both temperatures (581 vs. 600 g DM/d at high and low temperature respectively). In other studies on the effects of ambient temperature on feed digestibility, feed has commonly been provided *ad libitum* (Graham *et al.*, 1959; Kotb and Pfander, 1965; McDowell *et al.*, 1969; Moose *et al.*, 1969; Bhattacharya and Hussain, 1974; Christopherson, 1976; Conrad, 1985), so that any possible direct effects of ambient temperature were confounded by differences in FI. From the current results hypothesis a), that DMD would be higher at 50°/42°C than at 20°C when DMI levels were the same must be rejected.

The fact that WI at 50°/42°C in current experiment was still significantly higher (P<0.05) than at 20°C (2.8 vs. 2.0 l/d), may also have partly contributed to the differences in digestibility recorded between the temperature regimes. As argued by

Koes and Pfander (1975), higher WI may increase passage rate and reduce MRT, so that particulate digesta would have a shorter time to be subjected to rumen microbial digestion, and digestibility might then be expected to be reduced. Such an effect, if in operation, would have tended to reduce digestibility at 50/42°C in the current experiment.

The fact that MNP and EMNP were not significantly different at the temperatures studied is consistent with the findings of Chen *et al.*, (1992b) and Djouvinov and Todorov (1994) that EMNP is mainly influenced by DMI; DMI was controlled by pair-feeding in the current work and was thus almost identical at 50°/42°C and 20°C (Table 6.2). WI was slightly higher at 50°/42°C than 20°C (2.8 *vs* 2.0 l/d), and that difference might have been expected to increase rumen dilution rate, LOR and EMNP (Kennedy *et al.*, 1976; Van Soest, 1994). The failure of EMNP to show any such response in the current experiment cannot be explained from the available data, and leads to the rejection of hypothesis b.

The above results suggest that, apart from FI and WI, there are other factors that affect EMNP. One of those could be a detrimental effect of heat stress on rumen microbial activity. Studies on cows by Weldy *et al.*, (1964) and Kelley *et al.*, (1967) showed that the total VFA concentration declined at high ambient temperature, and since VFAs are waste products, from a microbial point of view, of anaerobic microbial metabolism in the rumen, their concentration can be taken as an indicator of rumen microbial activity. Thus a decrease in ruminal VFA concentration would, prima facae, indicate that microbial activity in the rumen had decreased. Another factor that may influence EMNP, through the rate of passage of particulate digesta from the rumen, is rumen motility. A study with cattle (Attebery and Johnson, 1969) demonstrated a decrease in the amplitude of rumen contractions as ambient temperature was increased from 18° to 38° C. Any decrease in rumen motility could be expected to reduce the rate of passage of particulate digesta from the rumen, and thus reduce EMNP.

The reduced volume of urine excreted by lambs at 50°/42°C as compared to those at 20°C confirms the results of the experiment of Rianto *et al.* (2002), and is consistent with the earlier suggestion of increased evaporative water losses at higher temperature The mean volume of urine excreted at 50°/42°C was 219 $\pm$ 23 ml/d in the current experiment, a value that is still considerably above the value of 130 ml/d that Schmidt-Nielsen (1964) suggested was the minimum urine volume for normal physiological function in heat stressed Merino sheep. The lowest individual daily urine volume recorded in the current experiment was 169 ml/d. From these results it is concluded that the physiological processes of PD excretion by the kidney are very unlikely to have been adversely affected in the current work, and that the MNP and EMNP values derived from the equations of Chen and Gomes (1992) can be accepted with confidence.

Conclusions

It can be concluded from the current experiment that:

1. Given the same DMI, and a slightly higher WI at 50°/42°C, a decrease in DMD and ND occurred at 50°/42°C as compared to 20°C.
2. Given the same DMI and a slightly higher WI at 50°/42°C than at 20°C, temperature had no significant effect on MNP and EMNP.
3. Further work is required to establish whether ambient temperature and WI influence LOR from the rumen, feed digestibility, EMNP, fermentative activity in the rumen (as evidenced by VFA concentrations and proportion), and rumen motility.

References

Attebery, J.T. and H.D. Johnson. (1969). Effects of environmental temperature, controlled feeding and fasting on rumen motility. J. Anim. Sci. 29: 734-737.

Bhattacharya, A.N. and F. Hussain. (1974). Intake and utilization of nutrients in sheep fed different levels of roughage under heat stress. J. Anim. Sci. 38: 877-886.

Chen, X.B. and M.J. Gomes. (1992). Estimation of Microbial Protein Supply to Sheep and Cattle Based on Urinary Excretion of Purine Derivatives - an Overview of the Technical Details. International Feed Resources Unit, Occasional Publication, Rowett Research Institute, Aberdeen.

Chen, X.B., Y.K. Chen, M.F. Franklin, E.R. Ørskov and W.J. Shand. (1992). The effect of feed intake and body weight on purine derivative excretion and microbial protein supply in sheep. J. Anim. Sci. 70: 1534-1542.

Christopherson, R.J. (1976). Effects of prolonged cold and the outdoor winter environment on apparent digestibility in sheep and cattle. Can. J. Anim. Sci. 56: 201-212.

Conrad, J.H. (1985). Feeding of farm animals in hot and cold environments. In Stress Physiology in Livestock: Vol. II. Ungulates, pp. 205-226 (M.K. Yousef, Ed.). CRC Press, Boca Raton.

Djouvinov, D.S. and N.A. Todorov. (1994). Influence of dry matter intake and passage rate on microbial protein synthesis in the rumen of sheep and estimation by cannulation and a non-invasive method. Anim. Feed Sci. Technol. 48: 289-304.

Graham, N. McC., F.W. Wainman, K.L. Blaxter and D.G. Armstrong. (1959). Environmental temperature, energy metabolism and heat regulation in sheep. 1. Energy metabolism in closely clipped sheep. J. agric. Sci., Camb. 52: 13-24.

Harrison, D.G., Beever, D.E., Thompson, D.J. and Osbourn, D.F. (1975). Manipulation of rumen fermentation in sheep by increasing the rate of flow of water from the rumen. J. agric. Sci., Camb. 85: 93-101.

Hungate, R.E. (1966). The Rumen and Its Microbes. Academic Press, New York.

Kelley, R.O., Martz, F.A. and Johnson, H.D. (1967). Effect of environmental temperature on ruminal volatile fatty acid levels with controlled feed intake. J. Dairy Sci. 50: 531-533.

Kennedy, P.M., R.J. Christopherson and L.P. Milligan. (1976). The effect of cold exposure of sheep on digestion, rumen turnover time and efficiency of microbial synthesis. Br. J. Nutr. 36: 231-242.

Koes, R.M. and W.H. Pfander. (1975). Heat load and supplement effects on performance and nutrient utilization by lambs fed orchard-grass hay. J. Anim. Sci. 40: 313-319.

Kotb, A.R. and W.H. Pfander. (1965). Ovine VFA metabolism under cold and hot conditions. J. Anim. Sci. 24: 892 (Abstr.).

McDowell, R.E., E.G. Moody, P.J. Van Soest, R.P. Lehmann and G.L. Ford. (1969). Effect of heat stress on energy and water utilization of lactating cows. J. Dairy Sci. 52: 188-194.

Moose, M., C.V. Ross and W.H. Pfander. (1969). Nutritional and environmental relationships with lambs. J. Anim. Sci. 29: 619-627.

Rianto, E., C.J. Thwaites and J.V. Nolan (2001). The effect of ambient Temperature and urea supplementation on feed digestibility and microbial protein production in lambs. J. Tropical Anim. Devpl. Special Ed. Oct. 2001: 58-67.

Rianto, E., C.J. Thwaites and J.V. Nolan (2002). The effects of water restriction at elevated ambient temperature on feed intake and digestibility, and microbial nitrogen production in lambs fed wheaten chaff. J. Tropical Anim. Devpl. 27: 83-87.

Schmidt-Nielsen, K. (1964). Desert Animals: Physiological Problems of Heat and Water. Oxford University Press, London.

Van Es, A.J.H., M.W.A. Verstegen, M.S.S. Youssef and H.J. Nijkamp. (1968). Some energy balances of dairy cows at high day and moderate night temperature. Neth. J. agric. Sci. 16: 136-141.