The effect of simulated altitude on the heat increment of feed in sheep

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1. Sheep given constant feed were exposed to environments in which the oxygen concentration in air was either 200 or 150 ml/l. There were no differences in daily heat production, methane production, urinary energy or faecal energy losses measured over periods of 4 d.

2. When the sheep were fasted there were no differences in heat production to be ascribed to the O_2 concentration in air. The thermic response to feed was unaffected by the O_2 concentration in the air.

Experiments by Miller & Stock (1969), Stock, Ferro-Luzzi & Norgan (1975) and by Stock & Miller (1976) have suggested that man's thermic response to food is reduced from that noted at sea level when he undertakes standard mild exercise at an altitude of about 3000 m. In the studies of Stock *et al.* (1975) a 10 % depression of the thermic response of resting man to food was noted at altitude, but this was not statistically significant. The major effect was only noted during exercise. Experiments with rats, however (Stock & Standish, unpublished results, data tabulated in Stock & Miller, 1976), suggest that simulated altitude abolishes the thermic response to feed in the normal unexercised animal. Rats were exposed to three environments, one with a normal oxygen tension and two in which the O_2 concentration was reduced to 140 ml/l and to 100 ml/l. Oxygen consumption in both the fasting and fed condition decreased as the O_2 concentration was reduced and the difference, the thermic response to feed was +0·34 ml O_2/100 g body-weight per min when the O_2 concentration was 210 ml/l and −0·24 when it was 100 ml/l. An O_2 concentration of 140 ml/l is equivalent to an elevation of about 3000 m and one of 100 ml/l to about 6000 m. Stock & Miller (1976) discuss the possibility that the effect might relate to changes in rate of absorption at altitude or to circulatory shifts. All the experiments quoted above were of short duration and it seemed desirable to ascertain whether the 24 h metabolism of animals was affected by changes in the O_2 tension of the air they breathe. Experiments were therefore made with sheep to measure the 24 h metabolism during fasting and during feeding, in two environments, one with an O_2 concentration of 200 ml/l and the other with the O_2 concentration reduced to 150 ml/l.

METHODS

Two wether sheep, nos. 60 and 69, 15 months of age and well trained to the respiration chambers, were used. They were given precisely 1000 g daily of a prepared pelleted diet, Ruminant Diet AA6 (Wainman, Smith & Dewey, 1975) in two meals each day. The diet was given for 2 weeks before the experiments began. The metabolism of each sheep was determined for four consecutive days on two occasions, once in an atmosphere in which O_2 concentration was 200 ml/l, and once in an atmosphere in which O_2 concentration was reduced to 150 ml/l. The sequence of these exposures was 200, 150 for sheep nos. 69 and 150, 200 for sheep no. 60.

The environments were produced within a closed-circuit respiration chamber (Wainman & Blaxter, 1967) by diluting the enclosed air with nitrogen on a wash-out principle. The

Table 1. *The energy exchanges of two sheep when kept in two environments*

Environment ...	Normal oxygen concentration		Reduced oxygen concentration	
	Sheep no. 60	Sheep no. 69	Sheep no. 60	Sheep no. 69
Actual oxygen concentration (ml/l)	201·7	198·7	150·3	152·0
Energy intake (kJ/d)	14804	14804	14804	14804
Faecal energy (kJ/d)	5153	5125	5177	4960
Urine energy (kJ/d)	743	773	701	732
Methane energy (kJ/d)	1534	1597	1542	1554
Heat (kJ/d)	8081	8124	8148	8167
Energy retained (kJ/d)	−707	−814	−763	−609
Fasting heat production (kJ/d)	4920	5138	4950	5171
Increment of heat (kJ/d)	3161	2986	3198	2996

amount of N_2 to be admitted was arrived at by calculation and the resultant O_2 concentration checked using a paramagnetic oxygen analyser.

There was no evidence of any daily trend in heat production during the 4 d of either exposure to low O_2 tension. The fasting experiments which followed those in which the sheep were fed lasted for 6 d and made use of this finding. The sheep were exposed for alternate 24 h periods to atmospheres containing 200 or 150 ml O_2/l. Sheep 60 was exposed to the sequence 200, 150, 200, 150 ml/l on the final 4 d of the fast and sheep 69 to the sequence 150, 200, 150, 200 ml/l.

Urine and faeces were collected quantitatively, their energy content determined by bomb calorimetry and their nitrogen content by macro-Kjeldahl.

RESULTS

The results obtained when the sheep were fed are given in Table 1. There were no effects which can be ascribed to the simulated altitude. The mean apparent effect on heat production of confinement in the low O_2 atmosphere was to increase heat production by 55 kJ/d, or by 0·6 %. This is within the known error range of repeated measurements of metabolism in sheep.

The fasting heat productions are also given in Table 1. The mean apparent effect of the lowered O_2 tension was to increase heat production by 25 kJ/d or 0·5 %, again well within the error range.

The mean increments of heat in the two atmospheres may be computed from the results as the difference between heat productions measured during feeding and fasting divided by the metabolizable energy ingested. For the normal atmosphere the heat increment was $3074 \div 7341 = 0{\cdot}419$ J/J and at the lower oxygen tension $3097 \div 7471 = 0{\cdot}415$ J/J. There was clearly no effect of a low content of oxygen in the atmosphere on the thermic response to food. The apparent difference in heat increment in absolute terms was 23 kJ/d in 3090 or 0·7 % of the metabolizable energy intake.

DISCUSSION

The above experiments with two sheep could not detect any effect of a reduction in the oxygen concentration in the air from 200 to 150 ml/l on any aspect of their 24 h exchange of energy. The instruments used were capable of detecting differences of 1 % in heat production (Blaxter, 1967) and these clearly did not occur. The sheep were confined in cages in the respiration chambers and undertook no exercise additional to that of normal cage life. The

small amount of muscular work undertaken does not enable the sheep results to be compared with those on the exercising human subjects studied by Stock & Miller (1976); it does, however, enable comparisons to be made with the rat experiments of Stock & Standish (unpublished results, data tabulated in Stock & Miller, 1976). The short-term measurements with rats showed depressions of both fasting and fed metabolism at simulated altitude and a reduced increment of heat. Neither occurred in the long-term experiments with sheep, suggesting that either the effect in the rat is transient or that there are major species differences in response to low O_2 tensions.

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