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Effects of sodium intake on lactation and Na levels in body fluids of Blackface ewes

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1. A low-sodium diet was given to Blackface ewes over two reproductive seasons; the diet provided 3–7 mmol Na daily, except for the period of lactation, when Na intake was increased to around 11 mmol/d. The diet of the control ewes was supplemented with sodium chloride to provide the recommended allowance of about ten times the level in the experimental low-Na diet.

2. Milk production was assessed during the first 2 months of lactation from incremental changes in the live weight of lambs during controlled sucking periods. Na and potassium were determined in milk and also in plasma, saliva and urine.

3. Neither yield nor concentration of Na and K in milk was affected by the level of Na in the diet. These results were supported by the similarity in live-weight gain of lambs in both years regardless of diet.

4. Plasma Na and K concentrations were not affected by the level of dietary Na. Na concentration in saliva and urine was significantly lower in the treated than in the control ewes, and K concentration in saliva was significantly higher.

The sodium content of some pasture herbage is as low as 0·1 g (4·3 mmol)/kg dry matter (DM) (Vincent, 1983), providing less than 10% of the Agricultural Research Councils' (1980) recommended daily maintenance allowance of 1·5 g (65 mmol) for 50–60 kg sheep. The effects of a diet containing Na at or near this low level on reproduction in Blackface ewes have been described by Vincent (1983). The effects of the same low-Na diet on milk production and on growth of lambs to weaning were determined in two consecutive reproductive seasons, year 1 and year 2, and are described here. The experiments were carried out at the Royal Veterinary College Department of Animal Health and Production, Potters Bar, Hertfordshire.

MATERIALS AND METHODS

Animals and management

Blackface ewes of mean weight $\simeq$60 kg were divided into two groups, one experimental (T) and the other a control (C) group, before mating in year 1. They were housed on wooden slats throughout the experiment except for the lactating period, when they were housed on concrete with straw bedding. The T ewes were given a diet very low in Na and the C ewes were given a similar diet, supplemented with sodium chloride to recommended levels. These diets were given continuously throughout the 2 years of study. The ewes were exposed to raddled entire Blackface rams for 6 weeks. Keel marks were recorded and crayons changed every 2 weeks.

A study of yield and Na and potassium composition of milk was carried out in both years on a representative subgroup (four in year 1 and five in year 2) of ewes given each diet. Only ewes with twin lambs were chosen, in order to maximize milk production and thus to potentiate any effects from low dietary Na. Two ewes of each group did not produce twins in the 2nd year, therefore they were replaced by similar ewes that suckled twins. In the 2nd year plasma, saliva and urine were collected during the lactation period for determination of Na and K.

In year 1 the study began 3 weeks after lambing and in year 2 it began 2 weeks after lambing. Results were collected over the subsequent 6 weeks in each year.

The ewes were individually penned for the lactation period with their lambs and no creep feed was offered. Milk production was determined from incremental changes in lamb weight during controlled sucking periods in the manner described by Peart (1968*a*, *b*). Milk intake was recorded over a 24 h period once weekly.

Lambs were separated from their dams for 8 h beginning at midnight before the day of recording and sampling; during the following period, 08.00 hours until midnight, lambs were allowed to suck for 10 min every 4 h. The difference in body-weight before and after sucking was taken as the milk yield over the preceding period. The five individual four-hourly milk yields thus obtained were accumulated to give an estimate of daily yield. There were no problems of weight loss in lambs caused by micturition and defaecation, since both generally occurred when the lambs were disturbed immediately before weighing.

During the first sucking, a milk sample was taken from the right half of each ewe's udder and analysed for Na and K. Daily live-weight gains of the lambs used in the lactation studies were calculated: these served as a useful additional guide to milk yield, not only for the 1st 3 weeks of lactation, when lambs are almost entirely dependent on milk (Owen, 1957), but also for the whole experimental period of about 2 months, since these lambs were given no access to creep feed.

Plasma, saliva and urine were collected to provide additional information on Na and K concentration in the body in relation to dietary Na intake. Blood was collected by jugular venepuncture and plasma was drawn off after centrifugation. Saliva was collected by wiping a pre-weighed piece of sponge (held between forceps) around the mandibular and sublingual area until the sponge was saturated. Urine was collected after briefly restricting respiration by covering the muzzle.

Diets and water

The daily maintenance requirement of Na for 60-kg ewes was estimated to be 1·5 g (65 mmol) from values compiled by the Agricultural Research Council (1965, 1980). Preliminary results from analysis of feedstuffs showed that the low-Na diet could be maintained at less than 10 mmol Na/d (Table 1). The adequate-Na diet required an extra 55 mmol/d, which was provided by addition of NaCl to the mineral and vitamin supplement. This supplement contained dicalcium phosphate, limestone, trace elements and vitamins in amounts that brought these constituents of the diet close to recommended values (Agricultural Research Council, 1980; Scottish Agricultural Colleges, 1978).

Table 2 shows the feed allowances and intakes at different stages of the reproductive cycle. The basic feedstuffs, oats, bran and wheat straw, were supplemented with maize-gluten meal in late pregnancy and in lactation to provide additional protein. The basal diet provided about 11 mmol Na/d during lactation. The T ewes were given rain-water containing 0·07 mmol Na/l; C ewes were given tap-water containing 3 mmol Na/l. The diet for C ewes was the basal diet supplemented with NaCl to provide a recommended 65 mmol Na/d in the maintenance ration and 96 mmol/d during lactation.

Mineral analyses

Plasma, milk and urine samples were diluted to appropriate levels and Na and K determined by atomic absorption spectrophotometry (Perkin–Elmer, 1973, 1976). Saliva weight was calculated by subtraction from dry-sponge weight. The sponge-plus-saliva was soaked in 5 ml concentrated hydrochloric acid and made up to volume. Portions were analysed in the same manner as plasma, milk and urine.

Table 1. *Sodium content of feedstuffs (mmol/kg dry matter) and water (mmol/l) samples taken at intervals over the 2-year experimental period*

(Mean values with their standard errors)

Feed	*n*	Na content Mean	SE
Oats	45	3·83	0·291
Wheat bran	45	2·52	0·091
Wheat straw	45	4·91	0·213
Maize-gluten meal	15	5·30	0·439
Tap-water	19	2·46	0·035
Rain-water	19	0·07	0·015

Table 2. *Daily feed allowances (air-dry weight; kg), estimated ME (MJ) and DCP (g) intakes and recommended daily allowances at different stages of the reproductive cycle of ewes given diets containing adequate (C) or low (T) levels of sodium*

Feed	Maintenance	Mating	Period before lambing* (weeks) 6–3	3–0	Lactation
Oats	0·5	0·9	0·55	0·8	1·8
Wheat bran	0·2	0·2	0·4	0·4	0·4
Wheat straw	0·3	0·3	0·3	0·2	0·2
Maize-gluten meal	—	—	—	0·05	0·2
Mineral–vitamin supplement					
C group	0·030	0·030	0·030	0·032	0·050
T group	0·027	0·027	0·026	0·028	0·046
Estimated intakes					
ME	8·20	12·15	10·47	13·09	24·90
DCP	58·6	87·5	84·4	124·8	264·6
Recommended allowances†					
ME	7·8	14·4	14·7	14·7	23·3
DCP	53	64	113	113	278

ME, metabolizable energy; DCP, digestible crude protein (nitrogen × 6·25).
* Twin-bearing.
† Ministry of Agriculture, Fisheries and Food (1976).

Statistical analyses

Means with their standard errors were calculated where appropriate. Significance was assessed by two-tailed Student's *t* test.

RESULTS

The estimated daily Na intakes and corresponding recommended allowances at different stages of the two reproductive cycles, year 1 and year 2, are given in Table 3. There was no evidence of feed refusal over the 2 years. The Na intake of the T ewes was generally only about 10% of that of C ewes and exceeded 11 mmol/d only during lactation.

Mean milk yields are shown in Table 4. The values were between 1·5 and 2 litres daily, and none of the treatment differences was significant. The average birth weight of the twin

Table 3. *Estimated and recommended total daily sodium intakes (mmol/d per ewe) at different stages of the two reproductive cycles of ewes given diets containing adequate (C) or low (T) levels of sodium*

Period	Estimated intake C	Estimated intake T	Recommended intake
Year 1			
Non-pregnant	65·1	3·9	65*
Mating	67·6	6·5	65*
Early pregnancy	64·5	3·9	65*
6–3 weeks before lambing	86·7	5·0	80‡
3–0 weeks before lambing	89·8	4·5	80‡
Lactation	108	10·1	96†
Year 2			
Non-pregnant	63·9	2·7	65
Mating	64·6	3·3	65
Early pregnancy	64·4	2·8	65
6–3 weeks before lambing	85·6	2·9	80
3–0 weeks before lambing	90·2	2·8	80
Lactation	116	11·8	96

* Estimated from values given by Agricultural Research Council (1980).
† Scottish Agricultural Colleges (1978).
‡ Estimated from Agricultural Research Council (1980) and Scottish Agricultural Colleges (1978).

Table 4. *Yields (l/d), sodium and potassium concentrations (mmol/l) and Na output (mmol/d) in milk over the lactation period of ewes given diets containing adequate (C) or low (T) levels of Na*

(Mean values with their standard errors for four ewes/group in year 1 and five ewes/group in year 2)

Ewe treatment		Yield	Na concentration	K concentration	Na output*
Year 1 (weeks 3–8)					
C	Mean	1·62	15·8	33·7	22·9
	SE	0·197	0·76	2·28	3·00
T	Mean	1·51	15·8	30·8	24·8
	SE	0·196	1·21	2·51	3·11
Year 2 (weeks 2–7)					
C	Mean	1·79	15·3	33·2	24·5
	SE	0·185	1·41	1·27	3·68
T	Mean	1·66	14·1	31·6	26·3
	SE	0·205	1·20	1·80	1·98

* Calculated means of individual net outputs rather than group means.

lambs used in the present study was about 4 kg, similar to that of the rest of the flock (Vincent, 1983). Daily live-weight gain (g/d) from birth to weaning at 8 weeks was: 182 (SE 16·2) (C, year 1), 203 (SE 7·7) (T, year 1), 184 (SE 5·7) (C, year 2) and 170 (SE 11·4) (T, year 2). There were no significant differences between the treatment groups.

The Na and K concentrations of milk samples are also shown in Table 4. The mean Na concentration was between 14 and 16 mmol/l and the K concentration between 30 and 34 mmol/l regardless of treatment or year.

Table 5. *Sodium and potassium concentrations (mmol/l) in plasma, saliva and urine over the lactation period (weeks 2–7) in year 2 of ewes given diets containing adequate (C) or low (T) levels of Na*

(Mean values with their standard errors for five ewes/treatment group)

Element	Treatment		Plasma	Saliva	Urine
Na	C	Mean	145·0	131·0	18·2
		SE	1·16	9·10	4·13
	T	Mean	143·0	74·4**	1·1**
		SE	1·28	12·97	0·35
K	C	Mean	4·5	20·4	74·6
		SE	0·22	6·28	25·25
	T	Mean	4·5	75·8**	81·7
		SE	0·27	13·32	30·43

Mean values were significantly different from the control value: ** $P < 0{\cdot}01$.

The Na output of the milk from each ewe was calculated and the mean values for each group are presented in Table 4. The overall mean was slightly less than 25 mmol/d. There was a decrease in output of Na with advancing lactation, but no effect of level of dietary Na.

Table 5 shows the Na and K concentrations in saliva, plasma and urine of these ewes during the lactation period. Plasma levels of both ions were unaffected by diet or year. In saliva and urine the Na concentration was significantly lower as a result of the low-Na diet; there was a concomitant rise in salivary K only.

DISCUSSION

There is little information on the Na requirements of sheep during lactation. Morris & Peterson (1975) fed lactating ewes for 8 weeks on dietary Na concentrations varying from 0·2 g/kg (8·7 mmol/kg) to 2·3 g/kg (100 mmol/kg). There was no effect on milk yield, concentration of Na in milk, feed intake or live-weight gain of lambs. The T ewes in the present experiment showed a similar ability to lactate normally over two reproductive cycles, on a diet containing only 0·1 g Na/kg (4·3 mmol/kg). In dairy cows, Smith & Aines (1959) found that milk yield but not Na concentration decreased after 1 year on low-Na intakes. This effect on the yield of dairy cows was probably associated with the relatively greater milk output per animal over a much longer period of the year in comparison with ewes. Towards the end of lactation in the present study, there was a small elevation in milk Na concentration in C ewes; this has been reported by other workers (Perrin, 1958; Ashton & Yousef, 1966). There was no evidence of such elevation in the T ewes.

The T ewes remained clinically healthy throughout the two reproductive seasons. This was somewhat surprising in view of the overall negative Na balance during lactation and probably during late pregnancy. In lactation, output from milk alone was around 25 mmol Na daily and intake was only about 11 mmol/d. From the saliva and urine values it is evident that there was conservation of Na and replacement by K where necessary in the body in order to maintain Na concentration above critical levels in milk. Plasma Na and K also remained unchanged throughout the experiment.

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