Influence of Inclusion of Salicornia Biomass in Diets for Rams on Digestion and Mineral Balance

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ABSTRACT : A metabolism trial was conducted with 28 Najdi rams allocated into seven dietary groups to evaluate the effect of dietary inclusion of *Salicornia bigelovii* Torr biomass on nutrient digestibility, ruminal fluid metabolites and nitrogen and mineral balances. Either the stems (ST) or spikes (SP) of this seawater-irrigated halophyte were incorporated into complete diets at rates of 0, 10, 20 and 30% levels, replacing equal amounts of rhodesgrass hay in a ground mixed control diet. Digestibility of DM, OM, EE, NFE and fecal and urinary nitrogen were not affected by increased level of ST in the diet. As level of ST increased from 0 to 20% in the diets, CP digestibility and nitrogen retention approached their maximum ($p<0.01$), whereas CF digestibility reached its minimum ($p<0.01$). On the other hand, except for EE, digestion of all nutrients and nitrogen retention were linearly depressed ($p<0.01$) as SP increased in the diets from 10 to 30% level. Concentration of ammonia-N, total VFA and pH values in the rumen fluid were lower ($p<0.01$) with the ST- or SP-fed diets than with the control diet. Increasing level of ST or SP in the diet was associated with an increase ($p<0.01$) in the proportion of acetate and a decline ($p<0.01$) in molar percentage of propionate in the ruminal fluid. Sodium absorption increased ($p<0.01$) with increased ST and SP in the diets up to the 10 and 20% level, respectively, followed by constant absorption values up to the 30% level. When the level of ST in the diet gradually increased to 30%, a concomitant increased ($p<0.01$) in Ca and P absorption were obvious; whereas, increased level of SP in the diets from 0 to 30% resulted in noticeable ($p<0.01$) depression in Ca and P apparent absorption. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 7 : 967-973*)

Key Words : Salicornia, Rams, Digestion, Mineral Balance

INTRODUCTION

Salicornia bigelovii Torr has shown promise as a seed crop for the production of oil under seawater-irrigation (Glenn et al., 1991). Several studies have shown that the biomass residues which remain after the harvest of mature spikes for oil production have potential as livestock feed (Glenn et al., 1992; Kraidees et al., 1998). The biomass is characterized by a high ash content of which Na is the principal constituent. Kraidees et al. (1998) reported that the Na content accounted for 6.44% and 12% of the dry weight of Salicornia stems and spikes, respectively. The ability of sheep to ingest high levels of Na from saltbush and Salicornia biomass without ill effects has been reported (Wilson, 1966; Glenn et al., 1992). Researches have indicated that high levels of Na in the feed increases water intake which enhances the flow of undegraded dietary nutrients from the rumen and resulted in increased protein digestion (Moseley and Jones, 1974; Hemsley et al., 1975), depressed the digestibility of dietary fibers (Hubbert et al., 1958; Weston et al., 1970) and altered the ruminal fluid characteristics (Hemsley et al., 1975; Arieli et al., 1989).

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The present work is aimed at investigating the effect of dietary inclusion of graded levels of Salicornia stems or spikes on the nutrient digestibility, ruminal fluid metabolites and nitrogen and mineral balances in Najdi rams.

MATERIALS AND METHODS

Preparation of diets

Salicornia stems and spikes were obtained from a single harvest of mature plants, which had been irrigated with seawater. Seeds were separated from the dried plants with a hammer mill, and then a seed cleaner was used to separate them. During the cleaning of seeds, empty spikes and small stems were collected in the combine bulk bin and referred to as "Salicornia spikes" (SP). Following seed harvest, coarse stems and few spikes were recovered as combine tailings, sun-dried and referred to as "Salicornia stems" (ST). The composition of ST and SP are presented in table 1. The dietary treatments were: a whole-mixed control diet containing 10% and 30% of alfalfa and rhodesgrass (*Chloris gayana*) hay, respectively, and six diets where either stems or spikes of Salicornia were incorporated at rates of 10, 20 or 30%, replacing an equal amount of rhodesgrass hay. The contents of other ingredients were also slightly modified to achieve isonitrogenous diets (on DM basis). Ingredients of each diet were then ground

Table 1. Feed ingredients and composition of experimental diets

Item	Stems (ST)	Spikes (SP)	Control diet	ST (%)			SP (%)		
				10	20	30	10	20	30
Ingredient, DM									
Yellow maize			36.4	36.55	36.65	36.65	36.75	37.35	37.65
Wheat bran			11.1	11.3	11.3	11.3	11.3	11.5	11.6
Soybean meal			12.0	11.8	12.0	11.7	11.6	11.1	10.7
Alfalfa hay			10.0	10.3	10.0	10.3	10.3	10.0	10.0
Rhodesgrass hay			30.0	20.0	10.0		20.0	10.0	
S. bigelovii stems (ST)	100			10.0	20.0	30.0			
S. bigelovii spikes (SP)		100					10.0	20.0	30.0
Trace mineralized salt[a]			0.45						
Vitamin premix[b]			0.05	0.05	0.05	0.05	0.05	0.05	0.05
Composition, DM									
OM	74.9	58.3	92.1	91.9	89.7	89.0	87.4	85.0	82.9
CP	5.1	6.6	16.4	16.3	16.4	16.7	16.6	16.2	16.3
EE	2.4	2.7	3.4	3.4	3.3	3.1	3.4	3.5	3.7
NDF	54.1	35.6	38.6	38.6	37.6	39.7	37.4	34.7	32.6
ADF	28.6	17.5	21.3	20.9	18.5	16.7	16.5	16.0	14.1
Ash	25.1	41.7	8.0	8.1	10.3	11.0	12.6	15.0	17.2
Na	6.4	12.0	0.51	1.0	1.4	1.9	1.6	2.7	3.7
K	0.8	1.5	1.01	1.0	0.9	1.0	1.0	1.1	1.1
Mg	0.4	0.9	0.29	0.4	0.5	0.6	0.4	0.5	0.5
Ca	1.0	0.6	1.1	1.1	1.3	1.2	1.3	1.2	1.1
P	0.1	0.1	0.6	0.6	0.6	0.6	0.6	0.6	0.7

[a] Contained per kg of trace mineral salt: $CoSO_4$, 0.68 g; $CuSO_4$, 10.4 g; $FeSO_4$, 35.7 g; ZnO, 7.5 g; $MnSO_4$, 10.7 g; KI, 0.52 g; and NaCL, 934.5 g.

[b] Contained per kg of vitamin premix: vitamin A, 9,500,000 IU; vitamin D, 3,300,000 IU; and vitamin E, 3500 IU.

through a 4.76-mm screen, mixed thoroughly in a stainless steel vertical mixer in batches of 100 kg to ensure uniformity.

Digestibility and nitrogen balance study

A metabolism trial was conducted with 28 rams averaging 50-kg body weight to determine the digestibility coefficient, the nutritive values and the nitrogen and mineral balance of the experimental diets. Rams were equally allotted to seven groups and fed *ad libitum* one of the seven experimental whole mixed diets (table 1). Rams were individually confined in false-bottom metabolic crates to facilitate separate collection of total feces and urine. After a 5-d transition period, during which the experimental diets were gradually introduced, a trial consisting of a 21-d preliminary period followed by a 7-d collection period was conducted. Weights of feed offered and refused were recorded daily, sampled, ground to pass through a 1-mm screen and stored. Throughout the collection period, water consumption was recorded daily at 8:00 and 16:00 h. Feces voided were collected before feeding in the morning, weighed and a 10% aliquot of total feces was dried at 65℃ for 24 hr. The dried samples were ground through a 1-mm screen and stored for later analyses. Total daily urine outputs of each ram was collected in a plastic bucket containing 100 ml 6 N HCl to prevent nitrogen losses, recorded and a 10% aliquot was sampled; at the end of collection period, samples of urine of each ram were mixed for nitrogen determination. On the last day of the digestibility trial, rumen fluid was collected via a stomach tube from each animal at 2 h after the morning feeding for measurement of pH values, volatile fatty acids (VFA) and aminonia-N concentrations.

Chemical and statistical analysis

Samples of ST, SP, experimental diets and feces were analyzed for moisture, ash, ether extract, crude fiber and crude protein according to AOAC (1990). Minerals in diets, feces, urine and drinking water were determined by the atomic absorption spectrophotometer procedure (model PU 9100, Philips). VFAs were measured by gas chromatography (model 404, Philips). Ammonia was determined by the distillation method using MgO (AOAC, 1990).

Feeding performance, digestibility, ruminal fluid characteristics and nitrogen and mineral retention data within either ST or SP levels were analyzed separately by ANOVA using the GLM procedure (SAS, 1988) according to the following model:

Table 2. Effect of increasing levels of Salicornia stems (ST) or Salicornia spikes (SP) in complete diets on feeding and drinking performances by Najdi lambs

Trait[a]	ST (%)				SP (%)			SEM	Probability[b]	
	Control	10	20	30	10	20	30		ST	SP
DM intake (kg/day)	1.74	1.70	1.71	1.62	1.69	1.26	1.10	0.12	NS	L**
OM intake (kg/day)	1.59	1.52	1.50	1.40	1.49	1.06	0.92	0.06	L**	L**
Water intake (l/day)	4.36	5.82	6.69	6.80	6.67	7.47	8.45	0.42	L**	L**
Water/kg DM (l/day)	2.5	3.4	3.9	4.2	3.9	5.9	7.7	0.23	L**	L**
Urine output (l/day)	1.7	2.7	3.1	3.7	3.4	4.4	5.5	0.43	L**	L**

[a] Data of control lambs were included in the statistical model of either ST or SP levels.
[b] L=Linear effect, Q=Quadratic effect and NS=Not significantly different ($p>0.05$); **$p<0.01$.

Table 3. Effect of increasing levels of Salicornia stems (ST) or Salicornia spikes (SP) in complete diets on nutrient digestion and nitrogen utilization by Najdi lambs

Trait[a]	ST (%)				SP (%)			SEM	Probability[b]	
	Control	10	20	30	10	20	30		ST	SP
Apparent digestibility (%):										
DM	65.0	66.0	69.8	67.7	65.7	61.8	58.7	1.82	NS	L**
OM	67.3	67.9	70.9	69.0	67.1	65.2	59.5	1.85	NS	L**
CP	73.9	73.3	76.9	73.5	74.8	70.4	67.9	0.92	Q**	L**
CF	45.9	44.8	39.9	40.2	36.7	33.1	15.5	2.31	Q**	L**
EE	70.3	72.7	70.7	73.5	71.8	70.2	69.6	0.94	NS	NS
NFE	72.9	72.3	73.0	74.8	71.8	69.7	65.8	1.12	NS	L**
Nutritive value:										
TDN	64.0	63.4	63.1	63.7	61.8	56.5	54.4	1.87	NS	L**
DCP	11.6	12.1	13.2	13.5	12.4	11.1	11.3	0.82	Q*	NS
Nitrogen balance:										
N intake, g/day	43.5	43.8	45.0	43.7	41.3	31.8	29.3	2.18	NS	L**
Fecal N (% of intake)	26.1	26.7	23.1	26.5	25.2	29.6	32.1	1.58	NS	L**
Urinary N (% of intake)	35.8	35.4	34.3	32.1	33.7	47.1	51.5	2.64	NS	L**
N retained (% of intake)	38.1	37.9	42.6	41.4	41.1	23.3	16.4	2.48	NS	L**
N retained (% of absorbed)	51.8	51.7	55.4	56.3	55.0	33.3	24.1	1.91	NS	L**

[a] Data of control lambs were included in the statistical model of either ST or SP levels.
[b] L=Linear effect, Q=Quadratic effect and NS=Not significantly different ($p>0.05$); *$p<0.05$; **$p<0.01$.

$$Y_{ij}=U+L_i+e_{ij},$$

where Y_{ij} is the j^{th} observation of the i^{th} ST or SP level, U is the common mean, L_i is the effect of i^{th} level of either ST or SP and e_{ij} is random error. Data of control rams were included in the statistical model of either ST or SP diets. The sum of squares was partitioned into linear, quadratic and cubic effects of either ST or SP levels using orthogonal polynomials.

RESULTS

The effects of feeding graded levels of ST or SP in the diets on ram intakes are presented in table 2. Rams fed diets containing increasing levels of ST in comparison with control-fed rams tended to have similar ($p>0.05$) DM intakes. On the other hand, increasing level of SP in the diet was associated with a linear ($p<0.01$) decline in DM intake. When rams were fed increasing levels of either ST or SP, daily OM intake exhibited a linear ($p<0.01$) decrease, but daily water consumption, water/DM ratio and urine output increased linearly ($p<0.01$).

Digestibility of DM, OM, EE and NFE were not affected ($p>0.05$) by increased level of ST in the diet (table 3). As level of ST increased from 10 to 20% in the diet, CP approached its maximum digestibility ($p<0.01$), whereas CF reached its minimum ($p<0.01$) digestibility; however, increasing level of ST to 30% in the diet resulted in no further changes. Fecal and urinary nitrogen, expressed as percentage of nitrogen intake, were constant for all ST-treatments. On the other hand, except for EE, digestion of all other nutrients were linearly depressed ($p<0.01$) as SP increased in the diets from 0 to 30% level. Fecal and urinary nitrogen, expressed as a percent of nitrogen

Table 4. Effect of increasing levels of Salicornia stems (ST) or Salicornia spikes (SP) in complete diets on ruminal fermentation characteristics by Najdi lambs at 2 h post-feeding

Trait[a]	ST (%)				SP (%)			SEM	Probability[b]	
	Control	10	20	30	10	20	30		ST	SP
pH	6.9	6.4	6.3	6.3	6.3	6.2	6.2	0.33	Q**	Q**
Ammonia-N, mg/dl	19.6	15.9	14.5	14.1	13.8	13.0	12.7	1.23	Q**	Q**
Total VFA, mmol	54.8	43.5	42.6	40.9	41.1	36.4	30.2	2.41	Q**	L**
VFA, mol/100 mol										
Acetic	69.4	72.1	72.0	71.7	71.1	73.1	73.9	1.33	Q**	Q**
Propionic	20.9	17.4	18.1	17.3	18.0	16.8	15.9	1.15	Q**	L**
Butyric	9.7	10.5	9.9	11.0	10.9	10.1	10.2	0.87	NS	NS

[a] Data of control lambs were included in the statistical model of either ST or SP levels.

[b] L=Linear effect, Q=Quadratic effect and NS=Not significantly different ($p>0.05$); **$p<0.01$.

Table 5. Intake, excretion and apparent absorption of dietary minerals in Najdi lambs fed increasing levels of Salicornia stems (ST) or Salicornia spikes (SP) in complete diets

Trait[ab]	ST (%)				SP (%)			SEM	Probability[c]	
	Control	10	20	30	10	20	30		ST	SP
Na intake, g/day	9.95	18.23	26.12	31.83	26.54	35.86	43.21	1.75	L**	L**
Fecal excretion	3.27	3.39	4.61	5.33	4.54	3.71	3.77	0.84	NS	NS
Urinary excretion	5.22	14.06	21.40	25.03	16.24	26.67	31.74	1.21	L**	L**
Apparent absorption, % of intake	67.1	81.4	82.4	83.3	82.0	89.7	91.3	3.65	Q**	L**
K intake, g/day	17.55	17.29	15.39	16.36	15.70	14.10	12.09	1.24	NS	L**
Fecal excretion	4.25	3.09	3.45	2.77	3.08	2.35	2.15	0.91	NS	NS
Urinary excretion	10.22	12.23	11.32	10.05	10.00	11.21	10.78	1.37	NS	NS
Apparent absorption, % of intake	75.8	82.1	77.6	83.1	80.3	83.3	82.2	4.71	NS	NS
Mg intake, g/day	6.39	8.07	10.62	11.67	7.75	8.24	7.90	1.48	L**	NS
Fecal excretion	2.62	3.26	3.90	3.93	3.27	2.81	3.56	0.53	NS	NS
Urinary excretion	0.90	1.49	1.31	1.11	0.99	1.33	1.40	0.23	NS	L*
Apparent absorption, % of intake	59.0	59.6	63.3	66.3	57.8	65.9	54.9	4.11	NS	NS
Ca intake, g/day	20.82	20.85	24.06	21.82	21.49	17.47	14.72	2.60	NS	L**
Fecal excretion	13.93	12.93	13.40	10.92	12.22	10.56	12.15	1.39	NS	NS
Urinary excretion	0.34	0.27	0.27	0.26	0.39	0.40	0.45	0.11	NS	L*
Apparent absorption, % of intake	33.1	38.0	44.3	50.0	43.1	39.6	17.5	3.04	L**	C**
P intake, g/day	9.91	9.66	10.60	10.21	9.32	7.81	7.25	1.04	NS	L*
Fecal excretion	8.58	7.65	7.90	6.92	8.12	7.31	7.19	1.13	NS	NS
Urinary excretion	0.22	0.27	0.25	0.22	0.15	0.62	0.94	0.21	NS	L**
Apparent absorption, % of intake	13.4	20.7	25.5	32.2	12.9	6.4	0.8	1.82	L**	L**

[a] Data of control lambs were included in the statistical model of either ST or SP levels.

[b] Mineral intake includes mineral from feed and drinking water.

[c] L=Linear effect, Q=Quadratic effect, C=Cubic effect and NS=Not significantly different ($p>0.05$); *$p<0.05$; **$p<0.01$.

intake, were linearly increased ($p<0.01$) as the level of SP in the diet increased. The corresponding effect on nitrogen retention showed linear decreases ($p<0.01$) as the level of SP in the diet increased.

Metabolites of rumen fermentation at 2-h post-feeding are shown in table 4. Concentration of ammonia-N, total VFA and pH values in the rumen fluid were lower ($p<0.01$) with the ST- or SP-fed diets than with the control diet. The concentration of ammonia-N in the rumen did not change as a result of increased level of ST or SP in the diets. Increasing ST in the diet from 10 to 30% level did not affect ($p>0.05$) the concentration of total VFA in the rumen, whereas increased level of SP in the diet was associated with a linear decrease ($p<0.01$) in VFA concentration. Increasing level of ST or SP in the diet from 0 to 30% was associated with a quadratic ($p<0.01$) increase in the proportion of acetate and a decline ($p<0.01$) in molar percentage of propionate in the rumen.

Mineral excretion and apparent absorption data have been summarized for ST- and SP-fed rams are presented in table 5. Dietary Na and Mg intakes increased linearly ($p<0.01$) with increased level of ST

in the diet; a similar response ($p<0.01$) for Na intake was noticed in rams fed graded levels of SP in the diets. On the other hand, increased level of SP in the diet was consistently associated with linear reduction in K, Ca ($p<0.01$) and P ($p<0.05$) intakes. Fecal mineral excretions were constant ($p>0.05$) regardless of level of ST or SP inclusion in the diet. When expressed as percentage of intake, apparent Na absorption increased ($p<0.01$) with increased ST in the diets up to the 10% level followed by constant absorption values ($p>0.05$) up to the 30% level. On the other hand, apparent absorption of Na increased linearly ($p<0.01$) in rams fed SP-diets. Apparent Ca and P absorption increased linearly ($p<0.01$) with increased ST level in the diet, whereas increased the inclusion of SP in the diet to over 10% level was associated with depression ($p<0.01$) in Ca and P absorption.

DISCUSSION

Feed intake

The control diet contained 5.1 g Na/kg DM and supplied more than adequate Na (NRC, 1985); accordingly the Salicornia-diets that contained in excess of 10 g Na/kg DM were considerably high. There is much evidence to show that a high concentration of NaCl in the diet will limit feed intake, and this concept has been used in controlling the consumption of concentrate feed in range livestock. The ability of sheep to ingest high levels of Na from saltbush and Salicornia biomass without ill effects has been known for some time (Wilson, 1966; Glenn et al., 1992; Kraidees et al., 1998). The results of this study show that DM intakes did not differ between the control and Salicornia diets containing up to 19 g Na/kg DM (30% ST-diet). Yet, increasing the amount of ingested Na to 27 g/kg DM (20% SP-diet) was associated with a concomitant depression in DM intake. Similar results were reported by Jackson et al. (1971) and Kraidees et al. (1998) who found that feed consumption by lambs did not decrease until Na content of the ration was greater than 25 g/kg DM. Kellaway et al. (1977) suggested that the renal capacity for concentrating Na was a factor limiting food intake when dietary Na was greater than 20 g/kg DM intake. Another line of reasoning was reported by Wilson (1966) who suggested that the decline in DM intake due to higher concentrations than 5% NaCl in food was attributable to the acceptability or taste of high salt diet (>20 g Na/kg DM) to the sheep. On the other hand, Meyer and Weir (1954) found little reduction in food intake when 13.1% NaCl was added to the food of sheep, even though the Na intake rose to 104 g/day. These discrepancies in results, together with the present paper, suggest that the effect of high Na on feed intake probably vary with the diet with which it is incorporated. Also, Wilson (1966) reported a wide variation in salt tolerance between different breeds and strains of sheep.

Digestibility and nitrogen balance

The changes in CP and CF digestibility were presumably a direct consequence of the higher mineral intake on digestibility of ST-diets. The daily intake of 26.1 g Na and the concomitant increases ($p<0.01$) in water consumption by the rams fed the 20% ST-diet, probably increased the ruminal dilution rate and thereby the rate of microbial protein synthesis (Harrison et al., 1975). In addition, the implied reduction of digesta-residue time in the rumen might have increased the flow of dietary protein to the small intestine and resulted in increased total protein digestion (Hemsley et al., 1975). On the other hand, the reduction of digesta-residue time might have depressed the digestibility of dietary fibers (Hubbert et al., 1958; Weston et al., 1970). In contrary to these, several reports have shown that the addition of Na supplements to diets did not affect the nutrient apparent digestibility (Nelson et al., 1955; Leibholz et al., 1980), however, in this study increasing the Na daily intake to 35.9 g/day (20% SP-diet) caused a general depression ($p<0.01$) in nutrients digestibility. Jackson et al. (1971) found that ingesting large amount of Na in excess of 40-g/day had an adverse effect on the rumen microflora that led to impaired the digestion of the food. Similar results were reported by Hemsley et al. (1975) who recorded a 24% depression in ruminal digestion of OM. Nevertheless, Nelson et al. (1955) showed that the nitrogen retention did not improve when the diet was supplemented with 20 g Na/day, but when the level of Na supplementation increased up to 40-g/day, the nitrogen retention decreased (Moseley and Jones, 1974). These findings agreed with the results of the present work in showing a decreasing nitrogen retention ($p<0.01$) with increasing Na intake from SP-diets (>35.9 g Na/day). This was due to the decreases in intake and apparent availability of nitrogen and to the increases ($p<0.01$) in fecal and urinary nitrogen excretions.

Ruminal fluid characteristics

Rumen pH values were lower ($p<0.01$) in Salicornia-fed rams as compared with those fed the control diet. A similar decrease in ruminal pH associated with increased NaCl has been observed in sheep (Tomas and Potter, 1975). This may be partly due to decreased salivary flow resulting from increased Na consumption (Warner and Stacy, 1977). Concentrations of total VFA and ammonia in the rumen were lower ($p<0.01$) with the Salicornia treatments than with the control. However, Salicornia

diets were associated with an increase ($p<0.01$) in the proportion of acetate and concomitant decrease ($p<0.01$) in propionate in the rumen. Hemsley et al. (1975), and Arieli et al. (1989) reported that ruminal molar percent of acetate increased and molar percent of propionate decreased at the higher levels of NaCl addition as compared with the control and this has been correlated with a shorter particulate retention time in the rumen, apparently due to the increase in water intake that is associated with the intake of such rations.

Water intake and mineral retention

The noticeable increases in water consumption probably reflected the amount of Na in the diet; the water intake was increased by about 94% and urine output increased by 223% for rams fed 30% SP-diet as compared with control-diet. This is consistent with the findings of Reffett and Boling (1985) and Arieli et al. (1989). The increased voluntary water intake is one of the principal adaptations, which allow the sheep to excrete excess Na load by an increase in glomerular filtration rate in the kidney (Tomas et al., 1973). In this respect, regardless of Salicornia incorporation level, most of the ingested Na was excreted in the urine (61-82%). These values were lower than the 89 and 98% obtained with sheep fed *ad libitum* on fresh leaves of saltbush and bluebush (Wilson, 1966) and by Tomas et al. (1973) when saline water was consumed by sheep, respectively. On the other hand, absolute amounts of Na, K, Mg, Ca and P excreted in the feces of control-fed and Salicornia-fed rams were unaffected regardless of level of incorporation, and suggests that absorption of these minerals from the gut remained unchanged. These findings are consistent with those reported by Nelson et al. (1955) and Tomas et al. (1973) when animals had high Na intakes. Therefore, the increased Na apparent absorption with increased level of SP in the diet was attributed to increased Na retention and excretion. Abouheif (personal communication) found that the muscles of sheep given 30% Salicornia spikes in their diet retained three times as much Na as normal muscle. Furthermore, the excretion of minerals via the suint and wool were not determined in this experiment, but measurements carried out by Potter et al. (1972) indicated that Na excretion via suint was increased in sheep drinking salt water. This may partly explain the increased Na absorption observed for those rams fed higher levels of SP-diets.

The changes in apparent absorption of K and Mg between ST-fed groups were non-significant but, for Ca and P, there were linear trends toward increased absorption ($p<0.01$) with increasing Na intakes up to 31.8 g/day. Similar results were reported by Moseley and Jones (1974) who found that phosphorous absorption increased with the increased levels of Na up to 3.1% in the diet of sheep. The changes in urinary excretion of Na, Mg, Ca and P observed when daily Na intakes exceeded 35 g/day were similar to those reported by Tomas et al. (1973). According to these authors the increases in the urinary excretion of Na will normally increases the quantity of each of the other minerals appearing in the urine, leading to reduce minerals retention. Thus, the depression in Ca and P apparent absorption observed with increasing levels of SP inclusion may be attributed to the decreased retention and food intakes with higher than 35 g of Na/day.

In conclusion, the incorporation of Salicornia biomass in the diets altered the patterns of digestibility and fermentation in the rumen, and may have increased the flow of undegraded dietary components out of the rumen. However, the results suggested that inclusion of ST up to 30% or SP at 10% in the diet did not have an adverse effect on the nutritive value of the diet or the nitrogen retention in Najdi rams if the fresh water was available.

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