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Utilization of dietary minerals and blood biochemical values in lambs fed hydrated sodium calcium alumino silicate sorbent material at supplementary level

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Abstract

An investigation was made in lambs to study the utilization of dry matter (DM), dietary minerals and changes in certain blood biochemical values due to the inclusion of hydrated sodium calcium alumino silicate (HSCAS) as a sorbent material in the concentrate mixture. Fourteen lambs of uniform age and body weights were allotted to two dietary groups, control (T_1) and experimental group supplemented with 5 g kg^{-1} of HSCAS (T_2). The feeding was continued for 105 days and the results indicated no variation in the intake of concentrate, hay and also the fortnightly body weight changes between the groups. Digestibility trial conducted showed that the dry matter (DM) consumption varied between 3.21 and 3.28% of their body weight and the ratio of concentrate and hay consumption was 37:63 (T_1) and 36:64 (T_2), respectively. The digestibility coefficient of DM between the groups varied non-significantly (T_1: 0.541 ± 0.018; T_2: 0.576 ± 0.023). Though the intake of minerals studied was similar in both the groups, the apparent gut absorption coefficients of copper (Cu: 0.239 ± 0.028 and 0.107 ± 0.010), Zinc (Zn: 0.279 ± 0.024 and 0.213 ± 0.019), Iron (Fe: 0.175 ± 0.015 and 0.128 ± 0.055) and Manganese (Mn: 0.423 ± 0.028 and 0.356 ± 0.015) were significantly (P < 0.01; 0.05) lower in lambs fed HSCAS. However the utilization of Calcium (Ca), Phosphorus (P) and Magnesium (Mg) did not differ. Analysis of blood plasma at 0, 50 and 100 days of feeding period for total protein, albumin, globulin and urea did not show any significant variation due to HSCAS feeding. It is concluded that inclusion of HSCAS at 5 g kg^{-1} concentrate mixture resulted in lower absorption of certain trace minerals (Cu, Zn, Fe, Mn) and thus it is required to additionally supplement these minerals in diet when such sorbent material is used.

Keywords: HSCAS; Sheep; Performance; Minerals; Biochemical parameters

1. Introduction

Various physical, chemical and biological approaches to counteract the mycotoxins present in animal feeds have been reported (Schell et al., 1993; Sweeney and Dobson, 1998). Among the physical methods, different adsorbents like activated charcoal, bentonite (Rao and Chopra, 2001) and hydrated sodium calcium alumino silicate (HSCAS: Ramos et al., 1996) are used as a prophylactic measure for the prevention of aflatoxicosis in farm animals. Among these, HSCAS is most thoroughly studied adsorbent and is widely used in farm animal diet for overcoming aflatoxin toxicity (Ramos and Hernandez, 1997). On the other hand, as the adsorption process involving such crystalline binders is more

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of a physical phenomenon, there is likelihood of binding of other essential nutrients like minerals, vitamins and amino acids present in gut digesta (Ramos and Hernandez, 1996), and making them less available for gut absorption. Hence, this investigation was conducted to examine the effects of including HSCAS adsorbent in diet of lambs on performance, mineral gut absorption and key plasma biochemical parameters.

2. Materials and methods

2.1. Experimental animals and feeding

Locally available lambs (Mandya cross breed) of 5–6 months of age were purchased from the farmers and after suitable adaptation, 14 numbers of lambs of uniform body weight and age were distributed equally to 2 groups of 7 lambs each in completely randomized design. All the lambs were vaccinated for common infectious diseases and were dewormed before the experimental feeding. The lambs in all the groups were fed for maintenance and for body weight gain of 50 g per day as per Indian Council of Agricultural Research (ICAR, 1985) requirements. Protein and energy requirements were calculated for each animal every 14 days based on body weight. Based on the nutrient requirement, the amount of concentrate (180 g DCP, 700 g TDN kg^{-1}) offered to each animal was at adjusted every 14 days interval to meet 80% of total protein requirement. The two groups were fed on concentrate mixture, control (T_1: maize 440 g kg^{-1}, wheat bran 250 g kg^{-1}, groundnut meal 300 g kg^{-1}, mineral mixture 5 g kg^{-1} and common salt 5 g kg^{-1}) and experimental (T_2: maize 435 g kg^{-1}, wheat bran 250 g kg^{-1}, groundnut meal 300 g kg^{-1}, mineral mixture 5 g kg^{-1}, common salt 5 g kg^{-1} and HSCAS 5 g kg^{-1}), respectively. The mineral mixture contained Ca (230 g), P (120 g), Mg (65 g), Fe (5 g), Mn (1.2 g), Zn (3.8 g), S (5 g), I (260 mg), Cu (770 mg) and Co (120 mg) per kg. The balance of protein and energy requirement was met by feeding ad libitum hay prepared out of local grass. The lambs were housed in well-ventilated shed free from any source of chemical contamination and provided artificial lights during nights at the experimental unit. All the lambs were individually tied in separate pen and fed concentrate mixture in a plastic trough daily between 08:30 and 09:00 h and hay was offered between 14:00 and 16:00 h. Fresh drinking water was made available at all times.

2.2. Parameters recorded

The experimental feeding was conducted for 105 days. Daily feed/fodder intake and fortnightly body weights were recorded. Blood samples were collected from each sheep at 0, 50 and 100 days of feeding experiment in heparinised tubes. The plasma was separated by centrifugation at $7840 \times g$ for 10 min and analyzed for total protein, albumin, globulin and urea spectrophotometrically using UV–visible Spectrophotometer (Varley et al., 1980).

2.3. Digestibility trial

During the sixth fortnight of feeding period, all the lambs were tied individually in stalls for 24 h period. Specially designed and stitched dung collection bags were tied for collecting the fecal pellets from each lamb throughout the 24 h period for 6 days. The pellets were removed from the bag at frequent interval and stored separately in polythene bags. The total quantity of fecal pellet obtained from each lamb was weighed daily and dried in hot air oven at $100 \pm 3\,^{\circ}C$ for overnight and dry matter (DM) was recorded (AOAC, 1990). The samples of binder (HSCAS)/feed/hay offered and residues, if any were also dried. The pooled dried samples of feces, feed and hay were ground to a fineness of 1 mm and about 3–4 g of sample material was taken in duplicate in silica crucible and subjected to dry ashing in a muffle furnace at 600 °C for 2 h. The ashed sample was cooled, weighed and dissolved in 5N HCl and filtered through No. 42 Whatman filter paper for mineral extract preparation (AOAC, 1990). The undissolved residue on the filter paper was again ignited and ashed in muffle furnace at 600 °C for 2 h, cooled and its weight recorded as the acid insoluble ash (AIA/silica).

Calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) were estimated as per the methods described in the analytical manual of atomic absorption spectrophotometer (AA 300, Perkin-Elmer, USA) using air and acetylene combination. For estimation of Ca and Mg, acid extracts were suitably diluted (1:50 or 1:100) with 0.1% lanthanum chloride to avoid interference from phosphates. Similarly for Mn, the samples were diluted with 0.5% calcium chloride. The atomic absorption spectrophotometer had a sensitivity of 5 ppm (Ca), 0.5 ppm (Mg), 5 ppm (Cu), 1 ppm (Zn), 6 ppm (Fe) and 2 ppm (Mn), respectively. Phosphorus was estimated colorimetrically by the molybdovanadate method (AOAC, 1975). Mineral standards were run during each analysis to confirm the accuracy of estimation.

2.4. Statistical analysis

The data on feed intake, body weight changes and biochemical parameters were subjected to statistical analysis in one-way classification using general linear model of systat 8.0. The significance among the treatment groups was tested by Duncan test based on the probability at 5 and 1% level (Snedecor and Cochran, 1967).

3. Results

3.1. Feed/fodder intake and body weight changes

The average daily intake of concentrate and hay in lambs did not vary between the two groups throughout the experimental period (Table 1). At the start of the experiment, the lambs consumed about 140 g of concentrate and 150 g of hay and during the seventh fortnight of feeding, the consumption of concentrate and hay was 175 and 290–300 g, respectively. The initial body weights in both the groups were 11.01 ± 0.97 and 11.17 ± 0.92 kg, respectively. Fortnightly body weight changes did not differ significantly, and at the end of the experiment, the body weights in groups 1 and 2 were 15.36 ± 1.61 and 14.50 ± 0.93 kg, respectively.

Table 1
Average feed/fodder intake in lambs (g/day/lamb)

Fortnight	Feed/fodder	T_1	T_2
Start	Concentrate	139.3 ± 2.30	140.0 ± 1.54
	Hay	150.0 ± 1.54	151.6 ± 0.78
	Total	289.3 ± 2.54	291.5 ± 1.34
I	Concentrate	140.4 ± 2.06	141.0 ± 1.91
	Hay	163.8 ± 2.65	165.0 ± 1.50
	Total	304.3 ± 1.70	306.0 ± 2.38
II	Concentrate	144.4 ± 2.03	141.3 ± 2.07
	Hay	163.7 ± 7.64	174.2 ± 1.32
	Total	308.1 ± 9.10	315.6 ± 1.07
III	Concentrate	150.0 ± 1.54	151.1 ± 0.99
	Hay	190.4 ± 2.79	185.0 ± 1.54
	Total	340.4 ± 3.44	336.1 ± 2.13
IV	Concentrate	160.0 ± 2.44	160.0 ± 2.44
	Hay	200.7 ± 1.70	205.7 ± 2.02
	Total	360.7 ± 3.69	365.7 ± 4.29
V	Concentrate	166.4 ± 2.54	170.0 ± 3.27
	Hay	229.2 ± 3.86	235.0 ± 1.54
	Total	395.7 ± 6.05	405.0 ± 3.93
VI	Concentrate	170.0 ± 3.09	173.7 ± 1.70
	Hay	268.3 ± 5.80	275.0 ± 7.72
	Total	438.2 ± 6.92	448.7 ± 7.90
VII	Concentrate	175.0 ± 3.27	174.3 ± 5.61
	Hay	300.7 ± 5.61	292.1 ± 5.10
	Total	475.7 ± 7.27	466.4 ± 8.29

3.2. Mineral content of feeds/fodder and binder

The diet 2, which was supplemented with 5 g kg^{-1} HSCAS contained higher ash, silica and other macro as well as micro minerals. The HSCAS contained 885.2 g ash, 628.6 g silica, 35 g Ca, 17 g Mg, 60 mg Cu, 69 mg Zn, 29 000 mg Fe and 1500 mg Mn per kg. The hay used for the feeding of lambs also contained moderate amount of most minerals (Table 2).

3.3. Dry matter and mineral utilization

The results of the digestibility trial indicated that total dry matter intake (g/lamb/day) did not differ between the groups (T_1: 478.8 ± 25.10 g; T_2: 453.9 ± 27.58 g) and they consumed DM at the rate of 3.21–3.28% of their body weight. The ratio between concentrate and hay intake was 37:63 (T_1) and 36:64 (T_2) in both the groups, respectively. The digestibility coefficient of DM varied from 0.541 ± 0.018 and 0.576 ± 0.023 and did not differ significantly. The intake of both macro and micro minerals in both the groups did not differ significantly. The apparent gut absorption of Ca, P and Mg was similar in both the groups but it was significantly ($P < 0.05$; 0.01) lower for all the trace minerals (Cu, Zn, Fe, Mn) in group 2 supplemented with HSCAS (Table 3).

3.4. Biochemical parameters

Analysis of blood plasma at periodic intervals for total protein, albumin, globulin and urea did not show any significant variation between the groups. The val-

Table 2
Mineral content of experimental feed/fodder and binder (DM basis)

Particulars	Ash (g kg^{-1})	AIA (g kg^{-1})	Ca (g kg^{-1})	P (g kg^{-1})	Mg (g kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
Diet 1	69.1	6.1	6.5	9.9	4.5	19.0	76	480	120
Diet 2	79.2	10.6	6.7	10.7	4.9	19.5	77	560	130
Hay	106.1	42.0	5.9	5.2	4.2	13.0	35	450	140
HSCAS	885.2	628.6	35.0	–	17.0	60.3	69	29000	1500

Table 3
Intake of dry matter (g/lamb/day) and utilization of minerals

	T_1	T_2
DM [Intake through (g)]		
Concentrate	177.0 ± 10.69	163.0 ± 12.10
Hay	301.8 ± 16.18	290.9 ± 18.47
Total	478.8 ± 25.10	453.9 ± 27.58
DMI (% BW)	3.21 ± 0.24	3.28 ± 0.20
Digestibility coefficient	0.541 ± 0.018	0.576 ± 0.023
Ca [Intake through (g)]		
Concentrate	1.1 ± 0.07	1.1 ± 0.08
Hay	1.8 ± 0.10	1.7 ± 0.11
Total	2.9 ± 0.15	2.8 ± 0.17
Level in DM (%)	0.6 ± 0.01	0.6 ± 0.02
Digestibility coefficient	0.237 ± 0.175	0.216 ± 0.030
P [Intake through (g)]		
Concentrate	1.8 ± 0.11	1.7 ± 0.13
Hay	1.6 ± 0.08	1.5 ± 0.10
Total	3.3 ± 0.18	3.2 ± 0.20
Level in DM (%)	0.7 ± 0.01	0.7 ± 0.01
Digestibility coefficient	0.195 ± 0.001	0.187 ± 0.006
Mg [Intake through (g)]		
Concentrate	0.8 ± 0.05	0.8 ± 0.06
Hay	1.3 ± 0.07	1.2 ± 0.08
Total	2.1 ± 0.11	2.0 ± 0.12
Level in DM (%)	0.4 ± 0.01	0.4 ± 0.01
Digestibility coefficient	0.219 ± 0.022	0.222 ± 0.016
Cu [Intake through (mg)]		
Concentrate	3.36 ± 0.20	3.17 ± 0.24
Hay	3.91 ± 0.21	3.67 ± 0.16
Total	7.27 ± 0.39	6.84 ± 0.37
Level in DM (ppm)	15.18 ± 0.07	15.08 ± 0.18
Digestibility coefficient**	0.239a ± 0.028	0.107b ± 0.010
Zn [Intake through (mg)]		
Concentrate	13.46 ± 0.80	12.51 ± 0.94
Hay	10.57 ± 0.57	10.18 ± 0.65
Total	24.02 ± 1.27	22.69 ± 1.42
Level in DM (ppm)	50.16 ± 0.42	49.95 ± 0.65
Digestibility coefficient*	0.279a ± 0.024	0.213b ± 0.019
		Fe[*Intakethrough*(*mg*)]
Concentrate	84.94 ± 5.14	91.26 ± 6.77
Hay	135.78 ± 7.28	130.92 ± 8.31
Total	220.72 ± 11.60	222.18 ± 13.55
Level in DM (ppm)**	460.6b ± 0.40	488.8a ± 1.53
Digestibility coefficient*	0.175a ± 0.015	0.128b ± 0.005
Mn [Intake through (mg)]		
Concentrate	21.22 ± 1.28	21.18 ± 1.58
Hay	42.25 ± 2.26	40.76 ± 2.59
Total	63.47 ± 3.31	61.94 ± 3.77
Level in DM (ppm)	127.56 ± 4.94	136.36 ± 0.12
Digestibility coefficient*	0.423a ± 0.028	0.356b ± 0.015

Means bearing different superscripts in a row differ significantly.
* $P<0.05$.
** $P<0.01$.

ues ranged between 4.53 ± 0.08 to 4.66 ± 0.14 g% (total protein), 2.56 ± 0.22 to 3.15 ± 0.08 g% (albumin), 1.38 ± 0.04 to 2.08 ± 0.12 g% (globulin) and 27.46 ± 1.17 to 35.83 ± 1.41 mg% (urea), respectively.

4. Discussion

Inclusion of HSCAS @ 5 g kg^{-1} concentrate mixture of lambs resulted in comparable and non-significant feed/fodder intake, suggesting no adverse effect on palatability. Most natural adsorbents are recognized as safe for animal feeding upto 2% of diet by Federal Drug Administration (FDA). The initial average body weight of lambs in both the groups varied between 11.0 ± 0.97 to 11.17 ± 0.92 kg. From third fortnight onwards, the average body weight in group 2 fed HSCAS was consistently lower and at the end of feeding period, lambs fed HSCAS gained 6.6% lower body weight as compared to control lambs, but was statistically non-significant. The mild growth depression trend probably would have become significant, if the feeding period is much more longer. Feeding of sodium bentonite or activated charcoal at 20 g kg^{-1} level in the diet of goats for 100 days did not have any negative effect on feed intake and growth rate (Rao et al., 2004a). Feeding HSCAS at 10 g kg^{-1} level in chick diet did not affect the performance and organ weights (Ledoux et al., 1998).

Relatively higher ash and mineral content recorded in diet 2 is due to the inclusion of HSCAS. The mineral contents in both the diets were more than the recommended levels for sheep (NRC, 1985). However the P level was more than the Ca in both diets due to the inclusion of wheat bran and groundnut meal as both are good sources of P than Ca (Gowda and Prasad, 2005). The binder (HSCAS) contained 688.6 g of silica, 35 g Ca, 17 g Mg per kg and excess of Fe and Mn probably be due to natural soil contamination.

The total DM intake as percent of body weight in both the groups varied from 3.21 to 3.28% and the proportion of concentrate and roughage was approximately 36:64, respectively. Some adsorbents have been known to impair nutrient utilization (Scheideler, 1993). Silicates adsorb organic substances either on its external surface or within its interlamillar spaces by the interaction with or substitution of the exchange actions (Dale et al., 1991). In the present study while the intake and utilization of DM, Ca, P and Mg were not affected by feeding HSCAS, the utilization of Cu (0.239 ± 0.028 and 0.107 ± 0.010), Zn (0.279 ± 0.024 and 0.213 ± 0.019), Fe (0.175 ± 0.015 and 0.128 ± 0.005) and Mn (0.423 ± 0.028 and 0.356 ± 0.015) were significantly ($P<0.01$; 0.05) lower in lambs fed HSCAS, indicating that the adsorbent has bound with the trace minerals making them unavailable for gut absorption. Addition of 20 g kg^{-1} HSCAS to tall fescue hay diets in sheep did not affect the apparent gut absorption of Ca, P, Na, K or Cu but significantly reduced the absorption of Mn, Mg and Zn (Chestnut et al., 1992). Feeding 5 or 10 g kg^{-1} HSCAS had no effect on phytate or inorganic P utilization in chicks (Chung and Baker, 1990). Addition of 10 g kg^{-1} sodium bentonite in the diet of growing pigs reduced the absorption and retention of Ca, P, Mg, Na, Zn and Fe and had no effect on K, Cu and Mn (Schell et al., 1993), suggesting the possibility of clay binding with some minerals in gut or that these minerals are required in gut for the purpose of osmotic balance. The lower percentage of trace minerals absorbed when clays are fed reflect the higher concentration of them in diets added with clays. In the present study, the level of Fe and Mn in total DM consumed were higher by 28.2 and 8.8 ppm in diet supplemented with HSCAS. When the mineral concentration in the diet exceeds the level of requirement by the animal, the efficiency of gut absorption is reduced (Georgievskii et al., 1982).

Montmorillonite silicate as a binder at 5 g kg^{-1} level in diet of rats reduced albumin and increased blood urea nitrogen (Abdel-Wahhab et al., 2002) and also reduced total and differential leukocytic count due to its effect on bone marrow in growing barrows (Harvey et al., 1994). Addition of 50 g kg^{-1} activated charcoal as a binder in the diet of lambs for 77 days had no adverse effect on hematocrit, serum Cu or Fe but it reduced the leukocyte count in blood and protozoa in rumen fluid (Hershberger et al., 1971). However, in the present study inclusion of 5 g kg^{-1} of HSCAS for 105 days did not cause any alteration in the level of total protein, albumin, globulin and urea in blood plasma at any stage of feeding experiment and the values were within the normal limits as described by Kaneko (1989). Similarly Ledoux et al. (1998) reported no changes in serum chemistry or any pathological changes in chicks fed 10 g kg^{-1} HSCAS in the diet. Rao et al. (2004b) also reported no changes in serum biochemical parameters (protein, albumin, globulin, urea, transaminases, alkaline phosphatase) due to feeding of 20 g kg^{-1} sodium bentonite or activated charcoal in the diet of goats.

5. Conclusion

It is clear from this study that inclusion of HSCAS at 5 g kg^{-1} level in the concentrate mixture of sheep for any prophylactic measure intended for preventing toxicity did not cause any major changes in dry matter intake, body weight gain, utilization of dry matter, Ca, P and Mg and certain biochemical values in plasma. However, the apparent gut absorption of Cu, Zn, Fe and Mn were significantly reduced, thus it is necessary to additionally supplement such trace minerals in diets when fed with adsorbent materials like HSCAS.

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