Effect of Varying Levels of Dietary Minerals on Growth and Nutrient Utilization in Lambs

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ABSTRACT : Hisardale male lambs (n=24, 4-5 month of age) were maintained on a conventional ration for a month, to equilibrate the body mineral status. Six lambs were sacrificed after one month of feeding; the samples of organs were analyzed to ascertain mineral status. The remaining 18 lambs were divided into 3 groups of 6 each on body weight basis. Three dietary treatments containing 100 (T_1), 110 (T_2) and 120% (T_3) of minerals (Ca, P, S, Zn and Mn) as specified by NRC (1985) were formulated and each treatment was alloted *ad libitum* to a group for 120 days. Blood and wool samples were collected at monthly intervals. At the end of the experiment a balance trial of 5 days duration was conducted to study the balance of mineral elements. The effective intake of minerals was Ca, 111 and 120, P, 110 and 122; S, 112 and 129; Zn, 112 and 126 and Mn, 109 and 123 percent in T_2 and T_3, respectively, in comparison to T_1 (100). The additional mineral supplementation had no significant effect on dry matter intake. The average daily weight gain was higher ($p<0.01$) in T_2 and T_3 than the control (T_1). The lambs under treatments T_2 (8.72) and T_3 (8.47 kg) consumed apparently lesser amount of dry matter per unit gain as compared to T_1 (10.81 kg). Significantly higher ($p<0.05$) dry matter and crude protein digestibility (%) were observed in T_2 and T_3 than in T_1. The mean balances for different elements were Ca, 1.14, 1.68 and 1.67 g; P, 1.70, 1.95 and 2.18 g; S, 0.54, 0.92 and 1.11 g; Zn, 22.56, 25.30 and 28.71 mg; Cu, 7.94, 5.71 and 5.53 mg; Fe, 33.19, 32.94 and 31.03 mg and Mn, 8.24, 14.40 and 16.07 mg/lamb/day. The retention of supplemental minerals increased ($p<0.01$) while that of Cu decreased ($p<0.01$) due to supplementation of minerals (Ca, P, S, Zn and Mn). Retention as per cent of intake increased statistically for S and Mn while that of Cu decreased. It can be concluded that supplementation of minerals (Ca, P, S, Zn and Mn) higher than the recommended level improved body weight gain and feed to gain ratio. The retention of minerals increased due to supplementation. Therefore, an additional supplementation of deficient minerals (Ca, P, S, Zn and Mn) by 10% was beneficial for Hisardale male lambs under tropical condition in India. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 1 : 46-52)***

Key Words : Minerals, Supplementation, Sheep, Requirements, Growth, Nutrient Utilization

INTRODUCTION

The minerals play important role in augmenting animal production and health, correcting deficiencies and preventing diseases through activation of immune system of the body. Minerals in adequate quantity and proportion need to be supplemented in addition to those available from different feeds. Acute mineral deficiencies show characteristic syndromes but the marginal deficiencies or excesses express non-specifically in the form of reduced growth, production, viability and fertility (Underwood, 1981). As there are no specific clinical symptoms, the detection of such borderline conditions is difficult. The umbrella concept of mineral inter-relationship is that if one element is in excess in diet may interfere the absorption or utilization of other element (Schuttee, 1984). Deficiency of minerals in sheep under grazing (Samanta and Samanta, 2002) and grazing plus concentrate supplementation (Mandokhot et al., 1987) has been reported. Supplementary need of minerals (Yadav and Mandokhot, 1988, Samanta and Samanta, 2002) and concentrate mixture to sheep of various ages under grazing has also been advocated (Karim and Verma 2001; Karim et al., 2001; Santra et al., 2002). Therefore, there is a need to determine the optimum concentration of different minerals in diet for developing effective supplementary package. Therefore, the present investigation was carried out to study the effects of different levels of mineral feeding in lambs on body weight gain, wool growth and nutrient utilization. In tropical conditions like India, the sheep are mainly thrived on poor quality roughages, fallen leaves. Moreover, the concentration of iron in feeds under tropical feeds is alarming (Mandal et al., 1996; McDowell, 1992). Thus, it is likely that the availability of minerals will be lesser. Again there is no standard for mineral requirements for Indian sheep; therefore, the NRC (1985) standard was taken as base.

MATERIALS AND METHODS

Experimental animals

Hisardale male lambs (n=24, 4-5 month of age), were dewormed and sheared. All the lambs were procured from State Sheep Breeding Farm, maintained on a common conventional ration consisting of gram straw and concentrate mixture supplemented with minerals to meet NRC (1985) requirements, for a month, including the

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Table 1. Mineral composition of basal concentrates, concentrate mixture of different dietary treatments and gram straw

Mineral supplements	Basal diet	T_1	T_2	T_3	Gram straw
Calcium (%)	0.20	0.36	0.47	0.57	0.61
Phosphorus (%)	0.51	0.63	0.72	0.80	0.21
Sulphur (%)	0.28	0.32	0.37	0.43	0.09
Zinc (ppm)	40	45	55	65	35
Copper (ppm)	11	11	11	11	23
Iron (ppm)	96	96	96	96	58
Manganese (ppm)	44	51	57	65	12

period of quarantine, to equilibrate the mineral status of the body. Six lambs were sacrificed after one month of feeding; the samples of blood, liver, kidney, heart and spleen were taken to estimate the mineral contents and the analyzed values were ascertained for mineral equilibrium through available reports (Georgievskii et al., 1981; McDowell, 1992) for mineral contents. The remaining 18 lambs were divided into three groups of 6 each, on the basis of body weight and were housed in well-ventilated animal sheds having the arrangement for individual tethering, feeding and watering.

Experimental rations and feeding

The concentrate mixture formulated contained maize 34.5; barley 35, groundnut cake 15 and wheat bran 15 parts and common salt 0.5 kg. The proximate composition (% on dry matter basis) of the concentrate mixture was dry matter (DM) 91.00%; crude protein (CP) 15.98%; crude fibre (CF) 7.00%; ether extract (EE) 4.02%; nitrogen-free- extract (NFE) 59.00% and total ash (TA), 14.00%; while the corresponding values in gram straw were DM 94.00, CP 3.50, CF 36.50, EE 2.50, NFE 50.70 and TA 6.80%. The feeding trial was continued for 120 days.

The concentrate mixture and gram straw were analyzed for calcium, phosphorus, zinc, copper, iron and manganese contents. The minerals, which found deficient (Ca, P, Mn, Zn and S) in daily ration of lambs, were supplemented through individual mineral salts (di-calcium phosphate-26.5% Ca, 20.5% P, sodium sulphate -Na_2SO_4, zinc sulphate $ZnSO_4$, 7 H_2O, manganese sulphate $MnSO_4$ H_2O). Under treatment T_1, the lambs had minerals calculated as per NRC (1985) requirements. However, under T_2 and T_3 the concentrate mixtures were supplemented to provide 10 and 20% higher minerals than in control (T_1), respectively. The mineral composition of basal concentrate, concentrate mixtures of different dietary treatments and gram straw are given in Table 1.

Weighed quantities of concentrate mixture and gram straw were offered to lambs to meet their crude protein (CP) and energy requirements as per recommendations of NRC (1985). The concentrate mixture was offered daily once in the morning to the animals individually followed by weighed quantities of gram straw. The water was offered *ad libitum* thrice a day.

Metabolism trial

After 120 days of experimental feeding, a metabolic trial of five days duration (collection period) was conducted. The trial included a five days cage adaptation period, which followed by a five days collection period. Representative samples of feed and ort from each treatment group were collected daily for chemical analysis. The total faeces voided were crushed, mixed thoroughly and representative samples were taken for dry matter and proximate principles. Similarly, one-twentieth amount of urine was collected in stoppered plastic bottles for estimating the minerals and stored in a deep-freeze until analyzed. The feed, ort and faeces samples were analyzed.

Collection of records and biological samples

Records of feed offered and ort were maintained daily. The lambs were weighed fortnightly before feeding and watering to assess the growth and to adjust the quantities of feed to be offered as per their increased requirement due to change in body weight. After the end of experiment all the lambs were defleeced manually using scissor and the wool production per lamb was recorded.

Chemical analysis

Samples of different experimental diets, ort and faeces were analyzed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and mineral matter (total ash) following the methods of AOAC (1975). Nitrogen-free-extract (NFE) was calculated by difference. Samples were analyzed for calcium, phosphorus and sulphur among macro-minerals and zinc, copper, iron and manganese among micro minerals. Calcium, zinc, copper, iron and manganese in feed, ort, urine and water samples were determined by Atomic Absorption Spectrophotometry method of Robbert and Issacland (1971). For phosphorus determination, the method of Jackson (1973) was followed. Sulphur in feed and faeces was determined by the method of Johnson et al. (1970) modified by Bull and Vandersall (1973), while the sulphur in urine was determined following the method of Stockhom and Koch (1923). Drinking water was also analyzed for different minerals but was found to be in non-detectable quantity.

The experimental data were statistically analyzed by the method of Snedecor and Cochran (1967).

RESULTS

The effective intake of different minerals were Ca, 111 and 120; P, 110 and 122; S, 112 and 129; Zn, 112 and 126 and Mn, 109 and 123 per cent of T_1 (100%) formulated

Table 2. Dietary intake of different minerals by lambs during feeding trial under different dietary treatments

Mineral	Treatments		
	T_1	T_2	T_3
Calcium (g/d)	3.77±0.15 (100)	4.17±0.20 (111)	4.52±0.21(120)
Phosphorus (g/d)	3.35±0.09 (100)	3.67±0.13 (110)	4.10±0.14 (122)
Sulphur (g/d)	1.63±0.04 (100)	1.82±0.06 (112)	2.11±0.07 (129)
Zinc (mg/d)	31.35±0.95 (100)	35.01±1.48 (112)	39.56±1.56 (126)
Copper (mg/d)	12.97±0.48	12.99±0.69	12.80±0.68
Iron (mg/d)	61.32±1.89	60.47±2.39	60.52±2.48
Manganese (mg/d)	25.36±0.64 (100)	27.58±0.90 (109)	31.33±1.04 (124)

Values in parenthesis are effective intake of minerals

Table 3. Body weight changes, dry matter intake and wool yield in dietary treatments

Attributes	Treatments		
	T_1	T_2	T_3
Initial body weight (kg)	15.20±0.69	15.06±1.14	15.55±1.11
Final body weight (kg)	23.43±0.45	25.75±1.13	25.55±1.47
Body weight gain (g/d)	68.58±5.00^{b}	89.08±3.51^{a}	83.33±3.69^{a}
DMI (g/d)	722±40.00	721±50.00	710±60.00
DMI (kg/100 kg b.wt.)	2.81±0.14	2.92±0.11	2.85±0.07
DMI (g/w $^{0.75}$ kg)	85.59±5.95	92.49±3.57	90.06±2.49
DMI: gain	10.81±1.12	8.72±0.74	8.47±0.33
Wool yield (g)	672.50±20.41	688.33±19.52	725.83±20.91

Each value is an average of six observations. $^{a, b}$: Values in row bearing different superscripts differ significantly ($p<0.05$).

Table 4. Digestibility (%) of dry matter and proximate nutrients in dietary treatments

Attributes	Treatments		
	T_1	T_2	T_3
Dry matter	59.09±2.22^{b}	69.41±2.47^{a}	65.07±1.93^{ab}
Crude protein	67.66±1.20^{b}	72.46±1.45^{a}	72.65±1.40^{a}
Ether extract	85.46±1.02	86.03±1.12	83.70±1.28
Crude fibre	39.43±1.85	42.48±0.76	41.54±0.87
Nitrogen-free-extract	60.66±2.69	66.85±1.46	53.46±5.64

Each value is an average of six observations. $^{a, b}$: Values in row bearing different superscripts differ significantly ($p<0.05$).

based on NRC (1985) recommendations.

Dry matter intake (DMI), body weight gain and wool yield

The average values of daily DMI (Table 3) were similar among the treatments. Though an apparent improvement in feed intake per unit body weight or metabolic body size was observed, but the values were statistically non-significant ($p>0.05$).

The average daily live wt. gains were 68.6, 89.1 and 83.3 g in T_1, T_2 and T_3 respectively (Table 2). The values observed in treatments T_2, and T_3, were significantly higher ($p<0.01$) than T_1, while those in T_2, and T_3 remained similar. The dry matter intake per kg gain was 10.81, 8.72 and 8.47 kg in dietary treatments T_1, T_2 and T_3, respectively (Table 3). Apparently lambs under treatments T_2 and T_3 consumed lesser amount of dry matter per unit gain, however the values were non-significant ($p>0.05$).

The average total wool yield was 672.5, 668.3 and 725.8 g in treatment T_1, T_2 and T_3 respectively (Table3). The values were statistically non-significant ($p>0.05$).

Nutrient digestibility

The effect of dietary treatments on apparent digestibility of dry matter, crude protein, crude-fibre, and ether-extract and nitrogen-free-extract is given in Table 4. Significantly higher ($p<0.05$) dry matter and crude protein digestibility was observed in treatments T_2 and T_3 containing higher levels of minerals than in control (T_1). However, no specific trend was observed in digestibility value of ether-extract, crude-fibre and nitrogen-free-extract.

Retention of macro-elements

The values of mean calcium balances under treatments T_2, and T_3, were significantly higher ($p<0.01$) as compared to T_1 (Table 5). However, there was no significant difference amongst the three treatments with regard to the retention of calcium expressed on percent intake. Significant ($p<0.01$) differences were observed amongst the treatments for phosphorus balance in lambs. The sulphur balance was progressively higher ($p<0.01$) with the increased dietary levels. The retention expressed as percent of intake, however, did not increase when S was

Table 5. Retention of macro-elements under dietary treatments during metabolic trial

Mineral	Treatments		
	T_1	T_2	T_3
Calcium intake (g/d)	3.31±0.05	3.99±0.14	4.51±0.05
Outgo (g/d)			
Faeces	2.01±0.03	2.22±0.40	2.63±0.07
Urine	0.15±0.12	0.22±0.02	0.27±0.01
Total outgo (g/d)	2.17±0.03	2.45±0.04	2.91±0.08
Balance (g/d)	1.14±0.02^b	1.68±0.15^a	1.67±0.08^a
Retention (per cent intake)	34.03±0.67	38.48±1.45	35.51±1.74
Phosphorus intake (g/d)	3.31±0.02	3.66±0.02	4.08±0.03
Outgo (g/d)			
Faeces	1.49±0.05	1.56±0.04	1.68±0.03
Urine	0.11±0.01	0.13±0.01	0.20±0.01
Total outgo (g/d)	1.61±0.06	1.70±0.03	1.88±0.03
Balance (g/d)	1.70±0.06^c	1.95±0.04^b	2.18±0.02^a
Retention (per cent intake)	51.35±1.85	53.52±1.09	53.61±0.61
Sulphur intake (g/d)	1.62±0.02	1.81±0.01	2.13±0.03
Outgo (g/d)			
Faeces	0.97±0.03	0.80±0.01	0.97±0.01
Urine	0.11±0.02	0.08±0.01	0.04±0.01
Total outgo (g/d)	1.08±0.03	0.88±0.01	1.01±0.01
Balance (g/d)	0.54±0.01^c	0.92±0.01^b	1.11±0.02^a
Retention (per cent intake)	33.53±1.10^b	51.19±0.35^a	52.24±0.64^a

Each value is an average of six observations. $^{a, b, c}$: Values in row bearing different superscripts differ significantly ($p<0.05$).

supplemented beyond 112% as the values in T_2, and T_3 were higher ($p<0.01$) as compared to T_1 (Table 5).

Retention of microelements

The daily retention of Zn increased linearly with the enhanced level of dietary Zn (Table 6). Significantly higher ($p<0.05$) balance (mg/d) was observed in T_1 as compared to T_2, or T_3. However, no difference was observed with respect to the percent retention of zinc. The retention of iron did not alter due to the treatments, while daily as well as percent retention of copper decreased ($p<0.01$) in T_2 and T_3 (Table 6). There were significant differences ($p<0.01$) between dietary treatments with respect to daily balance and percent retention of manganese.

DISCUSSION

Additional mineral supplementation did not influence dry matter intake statistically. The results are in agreement with the earlier findings of Field et al. (1982), Masters et al. (1988), Prabowo et al. (1988), Phillips (1990), Grace and Lee (1990), Alawa (1992) and Ryssen (1993), who also reported no change in dry matter intake of lambs fed higher levels of macro and microelements. Feeding of minerals at higher levels than the requirement resulted in enhanced body weight gain. Similar observations have also been reported by the other workers (Dologova and Ptaskin, 1986; Yadav and Mandokhot, 1988) in lambs given higher levels of macro-minerals. The supplementation of additional minerals resulted in improved digestibility of dry matter and crude protein, which might be the reason for increased body weight gain in dietary treatments T_2, and T_3. The results suggested an improvement of feed utilization due to supplemental minerals above NRC (1985) recommendation. An improvement in feed to gain ratio has also been observed on supplementation of S, Cu, Zn and Co in diets of young rams (Galatov, 1991).

The present observations were in line with the findings of Florescue et al. (1987), Masters et al. (1988), Doyle et al. (1992) and Grace and Lee (1992), who also observed no significant change in wool yield, on feeding of different minerals at different levels. On the other hand, Mercik et al. (1994) have reported higher greasy and clean wool yield with higher level of minerals in diet.

Other workers (Reid et al., 1987; Yadav and Mandokhot, 1988) have also observed no significant change in the digestibility of proximate nutrients in lambs given different levels of macro or micro minerals. In the present experiment there was an apparent improvement (ranging from 2.11 to 3.03%) in CF digestibility. Similarly, an improvement was observed in digestibility of some fibrous component of feed by lambs on supplementation of S (Cochran et al., 1991).

Field et al. (1985) also observed linear increase in retention of calcium with its increased dietary level. Similarly, retention of Ca and P was higher when diet was

Table 6. Retention of microelements under dietary treatments during metabolic trial

Mineral	Treatments		
	T_1	T_2	T_3
Iron intake (mg/d)	61.74±1.20	61.55±1.04	61.24±1.42
Outgo (mg/d)			
Faeces	27.15±1.64	27.56±0.84	29.19±0.90
Urine	1.39±0.09	1.05±0.01	1.01±0.01
Total outgo (mg/d)	28.55±1.99	28.61±0.85	30.21±0.89
Balance (mg/d)	33.19±0.81	32.94±1.01	31.03±0.90
Retention (per cent intake)	53.83±1.40	53.51±1.24	50.60±0.88
Manganese intake (mg/d)	25.48±1.10	27.21±1.20	31.54±0.80
Outgo (mg/d)			
Faeces	17.20±0.95	12.66±0.58	15.31±0.36
Urine	0.03±0.01	0.14±0.01	0.15±0.01
Total outgo (mg/d)	17.23±0.95	12.80±0.59	15.47±0.35
Balance (mg/d)	8.24±0.52^b	14.40±0.75^a	16.07±0.58^a
Retention (per cent intake)	32.44±1.66^b	52.91±1.18^a	50.20±0.81^a
Zinc intake (mg/d)	31.22±1.32	34.40±1.66	39.70±1.17
Outgo (mg/d)			
Faeces	8.40±0. 57	9.01±0.53	10.90±0.46
Urine	0.08±0.02	0.08±0.01	0.09±0.01
Total outgo (mg/d)	8.48±0.58	9.10±0.52	10.99±0.46
Balance (mg/d)	22.56±0.97^b	25.30±1.50^a	28.71±1.22^a
Retention (per cent intake)	72.88±1.27	73.73±1.53	72.24±1.32
Copper intake (mg/d)	12.52±0.92	12.55±0.80	12.53±0.83
Outgo (mg/d)			
Faeces	4.50±0.50	6.76±0.59	6.94±0.58
Urine	0.08±0.01	0.06±0.01	0.05±0.01
Total outgo (mg/d)	4.58±0.51	6.82±0.59	6.99±0.40
Balance (mg/d)	7.94±0.47^a	5.71±0.27^b	5.53±0.27^b
Retention (per cent intake)	63.91±1.61^a	46.04±1.60^b	44.54±1.17^b

Each value is an average of six observations. $^{a, b, c}$: Values in row bearing different superscripts differ significantly ($p<0.05$).

supplemented with additional quantity of these minerals (Hontert and Leng, 1991). The retention of Ca and P depended directly on intake in other study also (Gunther et al., 1989).

Increased retention of S was also reported when excess sulphate was supplemented in diet (Bray and Hemsley, 1969 and Kahlon et al., 1975). However, no significant positive correlation existed between retention and dietary intake of S (Bhandari et al., 1974) though Qi et al. (1993) observed a positive correlation.

The percent retention values decreased from 48.5-61.8 to 31.5-39.5 percent after 40 days of feeding (Kahlon et al., 1975). However, in the present experiment even after 10 days the retention of S in supplemented groups was 51.19 to 52.24. Thus, the hypothesis made by Kahlon et al. (1975) that the body becomes saturated with S after 20 days of feeding seemed to be unsound. The increased retention of it might be the reason for its higher concentration.

Though, the Zn is inter-related with Ca and P for absorption (Laflamme et al., 1985), however, the zinc level was also increased at the rate similar to that of Ca or P, and thus these macro minerals did not alter the availability of Zn. The increased level of Zn might have reduced the absorption of Cu as they involve common metallothionein protein as carrier at the site of absorption. In the present study, the level of Cu remained similar in all the treatments, but due to reduced availability, lower concentrations were observed significantly ($p<0.01$) in heart and liver, and apparently in spleen (Sharma et al., 2002). Supplementation of Mn improved its retention. While, a negative correlation between intake and retention has been observed by Waston et al. (1973), as Mn retention was more when the diet contained least Mn. Similarly, Ivan and Grieve (1976) observed lower retention at high dietary levels of Mn. The results obtained in this study, however, corroborated with its concentration in heart, kidney and spleen (Sharma et al., 2002).

The results indicated that supplementation of deficient minerals (Ca, P, S, Zn and Mn) higher than the recommended level (NRC 1985) improved body weight gain and feed to gain ratio. The retention of minerals also increased due to supplementation. Therefore, Hisardale male lambs under tropical condition in India should receive a 10% additional supplementation of minerals than the specified level.

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