

Research Article

Effect of Supplementation of Essential Cation, Anion or Combination of Both on the Digestibility of Cation Minerals in Diet of Cows

KIRAN BABU S., BANDLA SRINIVAS*

Dairy Production, National Dairy Research Institute, Bangalore 560030, India.

Abstract | Study was undertaken to assess the digestibility of essential cation minerals viz., Ca^{2+} , Mg^{2+} , Cu^{2+} , Zn^{2+} , Fe^{2+} and, Mn^{2+} when electrovalency of mineral supplement was positive or negative. Lactating Deoni cows were divided into 4 groups of 4 each in completely randomized block design and fed 8 KG fresh para grass, ad lib ragi straw and concentrate supplement without mineral mixture (control) or fortified with essential cation (T1) or anion (T2) minerals or both together (T3). The net electrical charge in the mineral mixtures in T1, T2 and T3 were +0.87, -1.55 and -0.64, respectively. DM ($p = 0.96$), OM ($p = 0.96$), CP ($p = 0.99$), Fe^{2+} ($p = 0.98$) and Mn^{2+} ($p = 0.83$) intakes were not significantly different between CG and TGs. Net charge in T2 affected CP digestibility adversely ($p < 0.05$). Ca^{2+} digestibility was apparently ($p = 0.29$) higher in T2 and T3. Lack of Phosphorus (P^-) source in T1 affected the Ca^{2+} utilization in comparison to T2 and T3. Mg^{2+} digestibility was higher ($P < 0.05$) in T2 and T3 than CG and T1. Cu^{2+} digestibility was not significantly ($p = 0.77$) different between groups. Zn^{2+} ($p < 0.01$), Fe^{2+} ($p < 0.01$) and Mn^{2+} ($p < 0.01$) digestibility was significantly different between CG and TGs and appeared that the net electrical charge of mineral mixture influenced the digestibility of opposite ions. Study concluded that cation mineral digestibility was better when net electrical charge of mineral mixture was negative.

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***Correspondence** | Bandla Srinivas, Dairy Production, National Dairy Research Institute, Bangalore 560030, India.; **Email:** bandla_srinivas@rediffmail.com

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INTRODUCTION

Underwood (1981) suggested 22 essential mineral elements to farm animals based on their concentration in the blood i.e., either >100 or < 100 mg/dl blood plasma and categorised to 7 macro and 15 micro minerals, respectively. Another classification was drawn on the basis of net electrical charge of ions such as cation or anion (Srinivas, 2012), which is relevant in the nutrition of higher forms of animals (Miller, 1981). Delaquis and Block (1995) discussed the dietary anion and cation concept with reference to the systemic acid-base balance of the animal that is basic for all nutrient transportation. Although dietary cation-anion balance (DCAB) is relevant in dairy animals, the con-

cept is restricted to balance between few cations (Na^+ and K^+) and, few anions (Cl^- , S^- and P^-). This needs to be extended to understand the functional importance of all essential mineral ions supplemented in mineral mixtures (Srinivas, 2012). Present study was conducted with an objective to evaluate the digestibility of essential cation mineral elements when net electrical charge (electrovalency) of mineral ion in the mineral mixtures was positive (cationic) or negative (anionic).

MATERIALS AND METHODS

ANIMALS AND DIET

Lactating Deoni cows were randomly distributed

into 4 groups of 4 animals each. Cows were fed with 8 KG of fresh para grass (*Brachiaria mutica*) and *ad lib* ragi straw (*Elusine coracana*) at 8 AM and 5 PM, respectively and, supplemented concentrate mixture (consisted of 35 parts of maize, 15 parts of groundnut meal and 50 parts of wheat bran without mineral mixture and common salt) in 2 equal parts twice in a day as per the requirements (ICAR, 1998). Control group (CG) was fed basal diet without additional mineral supplements apart from those naturally present in the diet. Treatment groups (TG) supplemented mineral mixture consisted of only essential cation (T1) or, anion (T2) minerals or, both cation and anion mineral elements together (T3) added to concentrate supplement fed in CG. Composition of mineral mixtures containing cation or, anion mineral compounds is presented in Table 1.

DIGESTIBILITY TRIAL

Digestibility trial was conducted after a preliminary period of feeding for 1 month. Trial consisted of 5 d of collection period. Body weight of animals, at zero hour of feeding and watering, recorded for 2 consecutive days before and after the trial. Faecal samples collected during trial period at 8:30 AM and sub-sampled to 1/400 parts. A part of sample was preserved with known quantities of 10 % H_2SO_4 (V/V) in pre-weighed glass bottles to estimate nitrogen (N). Dried samples of feed offered, left over feed (orts), and faeces were pooled for 5 d for chemical analysis.

CHEMICAL ANALYSIS

Dried samples of feed offered, orts, and faeces analysed for dry matter (DM), organic matter (OM), crude protein (CP) and total ash (AOAC, 2005). Minerals in feed and faecal samples were estimated using inductively coupled plasma (ICP) optical emission spectrometry (Optima 8000, M/s Pelkin elmer, Waltham, U.S.A) after predigesting the samples by modified method of closed system of acid digestion (US-EPA, 2001). The digested samples were cooled and filtered through Whatmann filter paper No1. Repeated washings were given to digestion tube and filter paper using Millipore water and final volume made to 10 ml. Subsequent dilutions were made as for the concentration of the element and estimated important cations viz., calcium (Ca^{2+}), magnesium (Mg^{2+}) copper (Cu^{2+}), zinc (Zn^{2+}), iron (Fe^{2+}) and

manganese (Mn^{2+}).

STATISTICAL ANALYSIS

Data were subjected to descriptive statistics and variances between groups mean were compared using CRD based on the following model:

$$Y_{ij} = \mu + T_i + B_j + e_{ij}$$

Where, Y_{ij} was any observation for which, μ was population mean, T_i was treatment effect, B_j was block effect, and e_{ij} was random error component (Das and Giri, 1991). Pairwise comparison between group means was tested by DMRT and significance was denoted by alpha superscripts with probability (p) ranged from 0.01 to 0.05.

RESULTS AND DISCUSSION

Dicalcium phosphate (Ca_2PO_4) was used as P⁻ source in the mineral mixtures although it contained cation Ca^{2+} . Similarly, iodide (I^-), molybdate (Mo^-) and selenite (Se^-) sources contained sodium (Na^{2+}) cation. Net electrical charge of the mineral mixtures supplemented in T1, T2 and T3 are presented in Table 2. Total quantity of mineral mixture supplemented in T1, T2 and T3 was 20.18, 18.10 and 31.36 g/d, respectively. Net ion electrical charge of mineral mixtures supplemented in T1, T2 and T3 were +0.87, -1.55 and -0.64, respectively. Chemical composition of the feedstuffs is presented in Table 3. DM (p = 0.96), OM (p = 0.96), CP (p = 0.99), Fe^{2+} (p = 0.98) and Mn^{2+} (p = 0.83) intakes were not significantly different between CG and TGs (Table 4). DM intake was numerically higher by 6 % in T2 and T3 where net charge of ions was negative. This is contrary to the observations of Hu et al., (2007). Mg^{2+} (p < 0.01), Cu^{2+} (p < 0.01) and Zn^{2+} (p < 0.05) ions intake were significantly different in CG, T1, T2 and T3.

CP digestibility was significantly reduced (p < 0.05) in T2 which could be probably because of more net negative charge of ions in the mineral mixture. Hu et al., (2007) reported adverse impact of net negative charge on CP digestibility in dairy cows. Although net electrical charge in T3 was negative, CP digestibility was not reduced. Considering the result of Hu et al., (2007) as well as CP digestibility observed in this study, we presume that CP digestibility might be

Table 1: Composition of ion specific mineral supplements.

Mineral ion	Mineral Source	Mineral supplement of (G/KG DM)		
		Cations	Anions	Cations + anions
Ca ²⁺	Calcium carbonate	7.58	—	—
Mg ²⁺	Magnesium carbonate	1.53	—	1.53
Na ⁺	Sodium sulphate	10.28	—	10.28
K ⁺	Potassium chloride	1.26	—	1.26
Cu ²⁺	Cupric carbonate	0.05	—	0.05
Co ²⁺	Cobalt carbonate	0.0005	—	0.0005
Zn ²⁺	Zinc carbonate	0.14	—	0.14
Ca ²⁺ & P ⁻	Dicalcium Phosphate	—	18.06	18.06
I ⁻	Sodium iodide	—	0.003	0.003
Mo ⁻	Sodium Molybdate	—	0.03	0.03
Se ⁻	Sodium Selenite	—	0.0025	0.0025

Table 2: Net charge of the ions in mineral supplements.

Mineral ion	Atomic mass	Cations	Anions	Net charge
CaCO ₃	100.09	3.9449	3.6351	0.3098
MgCO ₃	84.31	0.6590	0.8710	-0.2120
Na ₂ SO ₄	142.04	5.6483	4.6317	1.0166
KCl	74.55	0.6608	0.5992	0.0616
CuCO ₃	123.56	0.0306	0.0194	0.0112
CoCO ₃	118.94	0.0003	0.0002	0.0001
ZnCO ₃	125.42	0.0864	0.0536	0.0328
Ca ₂ PO ₄	175.13	8.2659	9.7941	-1.5281
NaI	149.89	0.0005	0.0025	-0.0021
Na ₂ MoO ₄	205.92	0.0067	0.0233	-0.0166
Na ₂ SeO ₃	188.94	0.0007	0.0021	-0.0014
Total	T1	10.9687	9.2110	1.2201
	T2	8.2738	9.8220	-1.5480
	T3	15.3592	15.9968	-0.6376

Table 3: Chemical composition of diet.

Parameter	Ragi straw	Green fodder	Concentrate
DM (g/Kg)	881 ± 18	178 ± 9	905 ± 2
OM (g/Kg)	896 ± 0.5	864 ± 3	908 ± 0.4
CP (g/kg)	25.60 ± 0.5	103.0 ± 0.1	20.22 ± 0.2
Calcium (g/kg)	10.3 ± 0.25	7.13 ± 0.26	9.40 ± 0.74
Magnesium (g/kg)	10.85 ± 0.24	10.15 ± 0.35	14.04 ± 1.01
Copper (mg/kg)	3.63 ± 0.28	55.13 ± 1.92	13.10 ± 1.51
Zinc (mg/kg)	213.40 ± 19.27	226.35 ± 5.07	470.40 ± 33.34
Iron (mg/kg)	95.88 ± 3.63	1341.00 ± 77.94	477.60 ± 22.60
Manganese (mg/kg)	384.90 ± 6.25	80.17 ± 5.05	126.30 ± 12.60

affected only beyond a threshold level of net negative electrical charge probably less than -1. Contrary to the observation of Popplewell et al., (1993) on cation

and anion balance in the diet of dairy cows, no significant impact of net charge of mineral supplements on DM and OM digestibility were observed between CG and TGs. Ca²⁺ digestibility was negative in few replicates and indicated individual cow variation. Ca²⁺ digestibility was apparently (p = 0.29) higher in T2 and T3. Probably lack of P⁻ source in the cationic mineral mixture affected the Ca²⁺ utilization in T1. In general, the ideal ratio of Ca²⁺ and P⁻ intake is 1:2 to 2:1 (Horst et al., 1994). Ca²⁺ to P⁻ ratio in Ca₂PO₄ is about 2:1. Mg²⁺ intake (p < 0.01), and digestibility (p < 0.05) were significantly different in CG and TGs. Mg²⁺ digestibility was higher in T2 or T3 than CG and T1. Mg²⁺ digestibility improved in T2 where mineral mixture consisted of anion mineral elements i.e., net electrical charge was negative. Weiss (2004) reported that mean apparent digestibility of Mg²⁺ was ranging from -0.04 to 0.33. According to NRC (2001), optimum Mg²⁺ digestibility is 43 %. Mg²⁺ digestibility in diet can be affected by increased K⁺ intake above the stipulated requirement in the diet (Weiss, 2004).

Intake of Cu²⁺ was significantly (p < 0.01) different between CG and TGs but, digestibility was not significantly (p = 0.77) affected Cu²⁺ in CG utilized more efficiently because it was in lower concentration than in TGs. According to Ivan and Grieve (1975) Cu²⁺ concentration in liver was inversely proportional to the dietary Zn²⁺ and, directly proportional to dietary Mn²⁺ supplementation. Mn²⁺ was not added in the cation mineral mixture but, Zn²⁺ was included. Zn²⁺ intake in CG or TGs was 15 folds higher than Cu²⁺. According to Weiss (2004), Zn²⁺ intake should not exceed the dietary Cu²⁺ intake by more than 5 folds. Probably, higher ratio of Zn²⁺ in the mineral mixture

Table 4: Feed and mineral intake and digestibility in different groups.

Parameter	Control	Mineral supplement (g/Kg DM)			SEM
		Cations	Anions	Combined	
Nutrient intake					
DM intake (kG/d)	6.46	6.40	6.60	6.61	0.35
OM intake (kG/d)	5.76	5.71	5.89	5.89	0.31
CP intake (g/d)	648.75	638.90	645.4	653.13	36.52
Calcium (g/d)	57.83 ^a	71.65 ^{bc}	65.42 ^{ab}	76.65 ^c	2.51*
Magnesium (g/d)	67.29 ^a	76.28 ^b	65.41 ^a	77.59 ^b	2.04**
Copper (g/d)	0.12 ^a	0.17 ^b	0.12 ^a	0.18 ^b	0.01**
Zinc (g/d)	1.78 ^{ab}	1.94 ^b	1.78 ^a	1.99 ^b	0.07*
Iron (g/d)	3.05	3.03	3.00	3.09	0.13
Manganese (g/d)	1.45	1.48	1.55	1.52	0.08
Digestibility coefficient					
DM	56.68	56.16	57.09	55.97	1.44
OM	58.96	58.65	59.69	58.68	1.42
CP	54.45 ^b	54.56 ^b	48.49 ^a	56.10 ^b	1.65*
Calcium	4.87	14.46	23.56	31.23	9.40
Magnesium	33.26 ^a	31.95 ^a	45.15 ^b	47.96 ^b	4.06*
Copper	62.59	58.11	55.53	58.54	4.74
Zinc	27.43 ^a	39.16 ^b	36.17 ^{ab}	58.56 ^c	3.14**
Iron	-4.96 ^a	2.40 ^{ab}	23.43 ^{bc}	35.78 ^c	7.05**
Manganese	41.46 ^a	44.54 ^{ab}	55.12 ^{bc}	64.15 ^c	3.50**

Mean values in a row with different superscripts a, b, c vary significantly; *P < 0.05, **P < 0.01

decreased the Cu²⁺ utilization even though both the elements incorporated as per the requirements (NRC, 2001). Zn²⁺ intake (p < 0.05) and digestibility (p < 0.01) were significantly different in CG and TGs. Significantly higher digestibility in T3 (59 %) than T1 (39 %) indicated that Zn²⁺ digestion improved in the presence of anion minerals such as P⁻, I⁻, Mo⁻ and Se⁻. Fe²⁺ intake was not significantly (p = 0.98) different between CG and TGs because, it was not fortified in the cation or cation + anion mineral mixture since Fe²⁺ availability from the diet was sufficient to meet the requirements. Fe²⁺ digestibility was negative in CG (-4 %) and significantly lesser than TGs (p < 0.01). Fe²⁺ digestibility was comparable between T2 (23 %) and T3 (36 %) but not with T1 (2 %). Fe²⁺ utilization also improved in the presence of anions; P⁻, I⁻, Mo⁻ and Se⁻, present in T2 and T3. Mn²⁺ intake was not significantly (p= 0.83) different as its availability in the basal diet was sufficient to substantiate requirement. Digestibility of Mn²⁺ was significantly (p < 0.01) different between CG and TGs. Mn²⁺ utilization also improved when net ion charge was negative. Cations homeostasis is partially dependent on endogenous faecal excretion controlled by the intestinal tract, liver and pancreas while, anions homeostasis is partially

dependent on renal excretion (Buckley, 2000) thus, enumerating both the ions are mutually exclusive but collectively exhaustive. According to Block (2011), subjects such as ratios of Ca²⁺ to P and N to sulphur, interactions between Mg²⁺ and K⁺, Mn²⁺ and Cu²⁺, and vitamin E and Se have been investigated and addressed however, no unifying concepts on mineral balances have been proposed yet. Our result indicated that utilization of some of the cation mineral elements e.g., Ca²⁺, Mg²⁺, Zn²⁺, Fe²⁺ and Mn²⁺ were improved in the presence of anion mineral elements P⁻, I⁻, Mo⁻ and Se⁻.

CONCLUSIONS

Study revealed that interaction between electrical charge carried by the cation and anion group of minerals in the mineral mixtures and their net electrovalency influenced the digestibility. Digestibility of cation mineral elements improved when net ion charge was negative.

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