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Growth Performance and Nutrient Utilization in Transition Sahiwal Calves Supplemented with Chromium, Zinc and Magnesium

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ABSTRACT

Minerals are essential for growth and reproduction and are involved in a large number of digestive, physiological and biosynthetic processes within the body. The aim of this study was to determine the effect of dietary supplementation of chromium (Cr), zinc (Zn) and magnesium (Mg) on the growth performance and nutrients utilization of calves during transition period. A total of 24 Sahiwal calves were randomly allocated into four groups (having six calves in each group) and fed for a transition period of 120 days (15 days of calf age to 135 days of calf age). Experimental calves either received a basal (devoid of supplemental Cr, Zn and Mg as control group) or supplemented with 0.15 mg Cr picolinate/kg $W^{0.75}$, 80 mg Zn/calf/day and 1.5 g Mg/calf/day. Experimental calves were monitored daily for feed intake and fortnightly for growth performance. At the end of the study, a digestion trial with 7 days collection period was conducted to study the effect of different treatments on nutrients utilization and mineral absorption. Results indicated that dietary Cr, Zn and Mg supplementation did not exert any effect on growth performance, dry matter intake (DMI), feed intake to gain ratio and apparent nutrient digestibility. However, the absorption of Cr, Zn and Mg was significantly ($P<0.05$) greater in its respective supplemented group. In conclusion, dietary supplementation of Cr, Zn, or Mg in Sahiwal calves during transition period did not influence growth performance, feed intake or nutrient digestibility but selectively enhanced mineral absorption.

KEYWORDS: Calves, Growth performance, Nutrients utilization, Mineral absorption, Transition period

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INTRODUCTION

Effective calf management is a critical yet often underdeveloped skill among dairy farmers. Deficiencies in feeding and husbandry practices, as noted by Thakur et al. (2025), can lead to significant future losses in production and reproduction. Research indicates that chromium (Cr) supplemented calf exhibits improved average daily gain (ADG) and feed efficiency. Studies, such as those reviewed by Windeyer et al. (2014), report that calves receiving organic Cr as Cr-yeast show significantly higher body weight gains and improved skeletal growth compared to non-supplemented controls. Improved glucose availability fuels immune cell activity, leading to lower morbidity rates and less growth disruption from disease, as noted by Calder et al. (2007). Zinc (Zn) is the second most abundant trace element in the animal body, but it cannot be stored in the animal's body (Zalewski et al., 2005) and requires regular dietary intake to meet its physiological needs. Zn influences various biological functions and is also a cofactor for more than 300 metalloenzymes (Chasapis et al., 2012). The magnesium (Mg) is an essential macro-mineral fundamental to optimal animal performance, influencing productivity, health, and metabolic efficiency across species. Mg is indispensable for glycolysis, oxidative phosphorylation and all energy-dependent processes, directly linking it to growth and milk production. Mg is a cofactor for enzymes in the Krebs cycle and for protein synthesis machinery (aminoacyl-tRNA synthetase) (Schonewille, 2012). Adequate Mg is directly linked to improved milk yield and component quality (NRC, 2001). Mg supports efficient rumen fermentation by stabilizing rumen pH and optimizing microbial protein synthesis. This leads to improved digestibility of forages and better ADG.

In the past, numerous studies in farm animals have been conducted with organic and inorganic sources of mineral supplementation for studying performance in calves. Studies with supplementation of Cr, Zn and Mg in Sahiwal calves are limited. Considering these facts, this study was designed to study the effects of Cr, Zn and Mg on the growth performance and nutrients utilization in young Sahiwal calves.

MATERIALS AND METHODS

Ethics approval, animal feeding and experimental design

All animal care and experimental procedures were approved by the Institutional Animal Ethics Committee (IAEC) of DUVASU, Mathura (Approval Number: IAEC/24/1/24). The study was conducted in strict compliance with the standards established by the IAEC, which is constituted according to Article 13 of the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA) rules, Government of India.

A total of 24 Sahiwal calves were randomly assigned into four groups (6 calves per group) on a basis of BW (28.12±0.90 kg) and age (15.0 days). 1) Control group: received a basal diet with no supplemental Cr, Zn or Mg; 2) Cr group: received the basal diet supplemented with 0.15 mg Cr/kg metabolic body weight ($BW^{0.75}$) provided as Cr-picolinate [$Cr(C_6H_4NO_2)_3$; molecular weight: 99.13 g/mol; minimum purity: 96%; Research Lab, Fine Chemicals Industries, Mumbai]; 3) Zn group: received the basal diet supplemented with 80 mg Zn/calf/day, provided as Zn-sulfate ($ZnSO_4$; molecular weight: 161.47 g/mol; minimum purity: 98%) and 4) Mg group: received the basal diet supplemented with 1.5 g Mg/calf/day, provided as Mg-sulfate ($MgSO_4$; molecular weight: 120.37 g/mol; purity: 98%). The experimental period continued for 120 days. The nutrient requirements for all the experimental calves were met according to the guidelines of the ICAR (2013). The nutrient composition of Calf starter and fodders offered, residue left and faeces voided during digestion trial was analysed for proximate analysis (AOAC, 2005), fibre fraction (Van Soest et al., 1991) and mineral content (5800 ICP-OES, Agilent, CA, USA). Milk and calf starter were offered @ 10% and 1% of the BW respectively. Green fodder and wheat straw were available *ad libitum*. The nutrient composition of basal diet (consisted of calf starter, green fodder and wheat straw and offered as TMR) fed during the animal feeding trial is presented in Table1.

Table 1. Composition of feedstuffs and milk fed during experimental period

Items	TMR
Ingredient composition	
Maize grain	17.5
Soybean meal	12.5
Mustard oil cake	6.5
Wheat bran	7.0
Gram husk	5.0
Mineral mixture	1.0
Salt	0.5
Wheat straw	20
Berseem fodder	30
Analyzed composition (g/kg DM or as mentioned)	
DM (% as fed)	71.01 (ranges between 70-73)
Total ash	10.09
AIA	3.24
EE	3.36
CP	17.18
CF	20.66
NFE	48.71
NDF	46.84

ADF	29.96
ADL	4.28
Ca	1.14
P	0.49
Na	0.82
K	12.44
Mg	0.90
Cu, mg/kg DM	8.80
Zn, mg/kg DM	28.21
Fe, mg/kg DM	272.36
Mn, mg/kg DM	51.21
Cr, mg/kg DM	0.28

Observation recording and laboratory analysis

The BW of experimental calves was recorded at the start and then fortnightly using a computerized scale (Leotronic Scales, India). Weighing occurred on two consecutive mornings at 06:00 h before feeding; the two-day average gave BW and ADG. A 7-day digestion trial was conducted to assessed nutrient utilization and mineral absorption. Feed, residue and faecal samples were dried at 60 °C to constant weight and ground through a 1-mm sieve for further analysis of DM, ash, ether extract and crude protein by AOAC (2005) methods; neutral and acid detergent fiber and lignin by following methodology of Van Soest et al. (1991). Mineral content in feed, residue and faecal samples were determined by using ICP-OES (5800, Agilent).

Statistical analysis

The data were collected and statistically analyzed by one-way analysis of variance (ANOVA) as per procedures suggested by Snedecor and Cochran (1994) by using SPSS (IBM SPSS Statistics V 20.0 USA). Animal tested within group was considered as a random effect, while group or treatment (Cr, Zn and Mg) was considered as the fixed effect. When the treatment was significant at $P<0.05$, means were compared by applying the probability of difference option of the least squares means statement. The animals were the experimental unit. Results were reported as means with SEM. Homogenous subsets were separated by Tukey's test.

RESULTS AND DISCUSSION

Growth performance

Dietary Cr, Zn and Mg supplementation did not exert any effect on growth performance (Table 2). Pandey et al. (2024) observed no improvement in growth with nano Cu or nano Zn supplementation in dairy calves. Consistent with these findings, Zaboli et al. (2013) found that ADG in goat kids was unaffected by Zn supplementation from different sources and levels, which aligns with the results of the present study. Similar to our findings, Khare et al. (2023) observed no significant ($P > 0.05$) influence of Cr on growth traits, while similar findings were reported in periparturient Murrah buffaloes (Deka et al., 2014) and calves (Mousavi et al., 2018). However, contrasting evidence exists. However, Kumar et al. (2021) reported significant improvements ($P<0.05$) in body weight and ADG in buffalo calves supplemented with Cr-chloride or Cr-picolinate. Kargar et al. (2018) further reported greater overall weight gain in Cr supplemented Holstein calves, although feed efficiency was unaffected. In contrast, other studies have demonstrated growth promoting effects of Zn. Umrao et al. (2025) who observed significantly higher ADG in the nano Zn supplemented Sahiwal heifers. Chang et al. (2020) observed increased ADG in newborn calves supplemented with Zn-methionine during the first two weeks of life, while Seifdavati et al. (2018) and Anil et al. (2019) reported higher body weight gain and ADG in calves receiving nano Zn supplementation. These variable responses across studies suggest that the growth effects of Zn supplementation depend on factors such as Zn source, dosage, physiological stage and baseline dietary Zn status. Work on the effect of supplementation of Mg in animals is very limited. The findings of the present study are consistent with those of Hernández-Calva et al. (2013), who reported no differences in ADG of feedlot lambs following Mg supplementation. In contrast, Aina (2013) observed a significant improvement in growth rate in West African dwarf goats when Mg was supplemented at a level of 0.50 kg/100 kg of DM. The discrepancy in growth performance in the findings of different studies may be a consequence of different sources and levels of Cr, Zn and Mg used, differing ages of animals used in the study, differences in sources and dose levels of the supplemental mineral, differences in study period, different genetics in various breeds, etc.

Table 2. Effect of Cr, Zn and Mg supplementation on growth performance during entire trial

Attributes	Group				P value
	Control	Cr	Zn	Mg	
Fortnightly BW gain (kg)	4.17±0.16	4.24±0.31	4.59±0.23	4.52±0.15	0.839
ADG (g/day)	277.78±10.39	282.50±20.40	305.76±15.41	301.44±10.28	0.837
DMI (kg/day)	1.23±0.04	1.28±0.03	1.38±0.08	1.36±0.04	0.729
DMI (kg/100 kg BW)	2.20±0.07	2.15±0.06	2.25±0.11	2.27±0.06	0.374
Feed intake to gain ratio	4.72±0.29	6.44±0.41	5.01±0.37	5.79±0.29	0.574

Feed intake

Dietary Cr, Zn and Mg supplementation did not exert any effect on feed intake. In the present study, no effects of supplementation of Cr, Zn and Mg were noticed on DMI (Table 2). The outcome aligns with numerous reports in ruminants, where organic Cr supplementation failed to alter DMI in dairy cows under thermoneutral conditions (Hayirli et al., 2001). Wang et al. (2023) reported increased DMI on Cr supplementation in cows. Mousavi et al. (2019) observed that Cr-methionine increased feed intake and DMI in dairy calves reared under hot summer conditions. This divergent response is theorised to be indirect. By enhancing insulin sensitivity, Cr may improve glucose metabolism and mitigate the catabolic effects of cortisol, thereby helping to maintain normal feeding behaviour under duress (Bernhard et al., 2012). Therefore, the absence of a DMI response in the current experiment may directly reflect the controlled, low-stress experimental environment, which did not provoke the metabolic dysfunction that Cr supplementation is intended to ameliorate. The absence of a response of Zn supplementation in the present study aligns with Umrao et al. (2025) who observed no significant effect on DMI in the nano Zn supplemented group in Sahiwal heifers. In opposite, Oconitrillo et al. (2024) reported that compared to control, Zn supplementation decreased the DMI throughout the trial in lactating cattle. Furthermore, the form of Zn is paramount. Organic complexes, such as Zn-methionine or Zn-proteinate, are often reported to be more bioavailable than inorganic salts like Zn oxide or sulfate, leading to more consistent improvements in intake and performance (Spears, 1996). This collective evidence strongly suggests that when animals are fed a well-formulated diet that meets or exceeds established Zn requirements (NRC, 2007), additional Zn provides no further stimulus for voluntary consumption. The results of this investigation demonstrated that Mg supplementation did not influence DMI in the studied animals. This outcome is consistent with a substantial body of ruminant research, where Mg supplementation, typically aimed at preventing hypomagnesemic tetany, has not been associated with increased voluntary feed consumption under non-deficient conditions. For instance, studies in feedlot cattle offered Mg oxide reported no effect on DMI (Colombo et al., 2021), and similar null findings have been documented in dairy cows when basal dietary Mg met established requirements (NRC, 2001). This suggests that Mg, unlike certain other minerals, does not function as a direct intake stimulant when adequate levels are present.

In the present study, statistical analysis of data revealed that variations between the groups for feed intake to gain ratio was non-significant. Results are in agreement with those obtained by Mousavi et al. (2018), who did not find any significant difference in gain: feed ratio in calves following dietary supplementation of different levels and sources of Cr. On contrary, Seifalinasab et al. (2022) observed that in Cr treated groups had lower daily feed intake as well as feed to gain ratio in the Cr-methionine (3 ppm) group than the control group finishing lamb. The present study was in agreement with Umrao et al. (2025) who observed no significant effect on FCR and FCE in the nano Zn supplemented Sahiwal heifers. On contrary, Liu et al. (2023) supplementary Zn of 80 mg/day from Zn-proteinate decreased the feed intake to gain ratio in calves during the whole experimental period of days 1 to 28. The findings align with present research indicating that Mg supplementation did not significantly affect feed conversion in feedlot lambs (Hernandez-Calva et al., 2013) and feedlot cattle (Colombo et al. 2022). In contrast, Orishchuk et al. (2025) found that an Mg based feed additive improved the feed conversion coefficient while reducing feed intake in laying hens. Likewise, Hashemi et al. (2012) reported a significantly lower FCR in ram lambs supplemented with MgO and sodium carbonate compared to the control group.

Nutrient utilization

The mean nutrient digestibility recorded over the 7-day metabolism trial indicated that Cr, Zn and Mg supplementation had no significant effect on apparent nutrient digestibility (Table 3). These findings are in agreement with Zade et al. (2014), who reported a non-significant effect on apparent nutrient digestibility in periparturient Murrah buffaloes supplemented with 0.5, 1.0, and 1.5 mg inorganic Cr/kg DM. Similarly, Kumar et al. (2013, 2015) also observed no differences in nutrient utilization when Murrah buffalo calves exposed to summer and winter conditions were fed diets supplemented with varying levels of inorganic Cr during the summer season. The present results are also consistent with the findings of Khare et al. (2023), who reported that dietary Cr supplementation did not influence nutrient digestibility in calves during transition period. In line with this, Wang et al. (2023) noted that the apparent digestibility of DM, organic matter, crude protein and ether extract remained unaffected by Cr supplementation in cows. In the present study, no effects of supplementation of Zn on nutrient digestibility were observed. Several studies have reported that Zn supplementation has little or no effect on nutrient digestibility in ruminants. The dietary supplementation of either nano Zn alone or in combination did not exert any effect on apparent nutrient digestibility in young cattle calves (Pandey et al., 2024). Similarly, Singh et al. (2018) further demonstrated that supplementation with either micro-ZnO or nano-ZnO at 60 ppm resulted in similar nutrient intake and digestibility coefficients in pre-ruminant lambs. In contrast, Abbi et al. (2024) observed that Zn supplementation significantly improved nutrient digestibility coefficients, with notable increases in NDF (P = 0.004) and ADF (P = 0.02) digestibility, along with a tendency toward higher DM digestibility. In the present study, no effects of supplementation of Mg on nutrient digestibility were observed. Limited work has been conducted to determine the effect of Mg supplementation on nutrient digestibility in animals. On contrary, Orishchuk et al. (2025) reported that supplementation with a Mg based feed additive improved nutrient digestibility in laying hens whereas. Accordingly, Xiong et al. (2024) observed that Mg supplemented feedlot lambs exhibited higher total tract nutrient digestibility compared to controls. This apparent disagreement in nutrient digestibility among different experiments could be due to the chemical form of Cr, Zn and Mg used or the minerals level was too low to affect the nutrient digestibility in the present study.

Table 3. Effect of Cr, Zn and Mg supplementation on nutrient utilization (%)

Nutrient	Group				Pooled SEM	P value
	Control	Cr	Zn	Mg		
DM	61.41	61.95	62.60	61.59	0.13	1.000
OM	69.11	69.60	70.46	69.39	0.15	0.685
CP	74.12	71.24	73.16	71.87	0.32	0.443
EE	77.29	78.28	81.22	80.43	0.46	0.675
CF	53.94	55.22	54.93	53.53	0.20	0.589
NFE	71.08	73.67	72.54	71.73	0.28	0.289
NDF	51.24	52.46	52.18	50.85	0.19	0.675
ADF	33.31	34.10	33.92	33.05	0.12	0.958
Ca Absorption (%)	38.19	38.82	39.09	38.48	0.20	0.759
P Absorption (%)	48.94	50.29	48.38	50.41	0.50	0.586
Na Absorption (%)	87.38	90.32	88.49	89.25	0.62	0.576
K Absorption (%)	84.17	85.32	86.01	85.78	0.41	0.384
Mg Absorption (%)	24.92[a]	28.62[a]	30.21[ab]	33.09[b]	0.48	0.037
Cu Absorption (%)	10.40	10.39	10.23	10.79	0.12	0.493
Zn Absorption (%)	23.74[a]	23.65[a]	34.06[b]	24.14[a]	2.56	0.043
Fe Absorption (%)	28.38	29.99	28.93	27.39	0.57	0.475
Mn Absorption (%)	4.03	4.02	3.19	3.29	0.23	0.392
Cr Absorption (%)	2.44[a]	6.42[b]	2.04[ab]	2.08[a]	0.91	0.028

Values within a row with different superscript letters differ significantly ($P<0.05$).

Mineral absorption

However, treatment showed a significant ($P<0.05$) effect on the intake, faecal excretion and absorption of Cr, Zn and Mg (Table 3). The treatments showed a significant ($P<0.05$) effect on the intake, faecal excretion and absorption of Mg. Also, the findings of the present study revealed a significant ($P<0.05$) effect of Zn supplementation on its intake, faecal excretion and absorption. Intake, faecal excretion and absorption of Zn were significantly ($P<0.05$) higher in Zngroup compared to the control, Cr and Mg groups. Similarly, intake, faecal excretion and absorption of Cr were significantly ($P<0.05$) higher in the calves supplemented with Cr compared to the calves of the control, Zn and Mg groups. In the present study, the absorption of Cr, Zn and Mg was significantly ($P<0.05$) higher in the Cr, Zn and Mgsupplemented groups respectively as compared to the calves of the other groups, indicating minimal interaction between Cr and other studied minerals. These findings are consistent with studies on Cr-chloride supplemented heifers showed higher trace mineral intake (Biswas et al., 2006), and apparent Cr absorption is known to vary by source, ranging from 4-10% for inorganic Cr to 10–25% for natural sources such as brewer's yeast (Underwood, 1977). Some contrasting observations exist, including increased Zn, Cu, and Fe intake in CrCl3-supplemented heifers (Biswas et al., 2006) and decreased Zn absorption (Underwood, 1977). Overall, the findings indicate that Cr supplementation effectively enhances Cr status without consistently affecting the metabolism of other trace minerals. In the present study, Zn absorption was higher in the Zn supplemented group while its supplementation had no effect on the absorption of other minerals. These results are consistent with Pandey et al. (2024), who reported higher absorption and bioavailability of Zn in the 30 ppm nano-Zn and combination (10 ppm nano-Cu and 30 ppm nano-Zn) groups, with no interaction between other minerals. Similarly, Liu et al. (2021) found that Zn-methionine added to feed and Zn sulphate in drinking water significantly $P<0.05$) increased its absorption and Zn concentrations in the liver and jejunum of piglets. As similar to the findings of the present study, Garg et al. (2008) also reported no significant differences in Ca and P balance or retention among lambs supplemented with Zn-methionine complexes, ZnSO4, or control diets. The present findings in agreement with Ramirez et al. (1998) who observed that the Mg absorption in Holstein steers enhanced by increasing dietary Mg level. Various factors played a crucial role in Mg absorption. Mg is more soluble at lower rumen pH, enhancing its availability for absorption (Martens et al., 2018). In the present study, dose dependent absorption of Cr, Zn and Mg in respective groups with no effect on the absorption of other studied minerals is indicative of no interaction among Cr, Zn and Mg with dietary minerals.

CONCLUSION

In present study, it would be rational to conclude that dietary supplementation with Cr, Zn, or Mg during the transition period did not result in significant alterations in growth performance, DMI, feed efficiency or apparent nutrient digestibility in Sahiwal calves. The lack of response in productive parameters indicates that the basal diet was likely adequate to meet the nutritional requirements for growth during the study period. Nevertheless, dietary inclusion of these minerals significantly enhanced their respective absorption, demonstrating improved mineral bioavailability. These findings suggest that while Cr, Zn and Mg supplementation may not directly influence growth under normal conditions, they could play a supportive role in maintaining mineral status. Further investigations are required to assess their potential benefits under conditions of nutritional deficiency, physiological stress or enhanced production demands in transition calves.

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