RESEARCH ARTICLE

Effect of Supplementation of Calcium Propionate on Nutrient Digestibility and Milk Yield in Dairy Cattle

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Abstract

Present study was carried out on twenty-four lactating dairy cows (HF × Jersey, Jersey × Sahiwal) to assess the effect of feeding different levels of calcium propionate for 40 days on nutrient digestibility, milk yield and milk composition. The cows were divided into four groups having six animals in each group and randomly allotted to four dietary treatments, *i.e.* T_1 (control diet) (*ad libitum* APBN-1 green fodder, concentrate pellet feed and paddy straw) with no calcium propionate supplementation. Group T_2, T_3 and T_4 were fed control diet with 60 g, 70 g, and 80 g calcium propionate/cow/day, respectively. After 30 days feeding, a digestion trial of 7 days was conducted. The digestibility (%) of DM, OM, CP, EE, CF and NFE were found to vary significantly ($p<0.05$) among treatments, and increased with increasing level of calcium propionate compared to control group. The digestibility (%) of cell wall fractions, ADF and NDF, though improved, did not vary significantly. Average dry matter intake (kg/day) was 9.98, 10.34, 10.27 and 10.45 and the feed conversion ratio in terms of milk yield was 2.31, 2.27, 2.29 and 2.16 for T_1, T_2, T_3 and T_4, respectively, indicating an increasing trend in DMI, eventual increasing milk yield, though there was no significant variation in the milk composition. It was concluded that supplementation of higher dose of calcium propionate improved the nutrient digestibility and milk yield than middle and lower levels.

Key words: Calcium propionate, Digestibility, FCR, Milk composition, Milk yield.

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Introduction

Dairy is the main source of income for livestock entrepreneurs in an agricultural nation like India. However, dairy cows, especially those in the advanced pregnancy and early lactation, are not getting enough feed to meet their energy needs for producing milk, hence experience a period of negative energy balance during the transition period, which causes them to lose weight. Dairy cows are particularly vulnerable to metabolic diseases during the transition period. The increasing incidences of dystocia, uterine prolapse, retained placenta, metritis, displaced abomasum, and other metabolic illnesses, such as calcium tetany, are described as risk factors that limit milk production (Serrenho *et al.,* 2021). According to reports, to combat negative energy balance during the early lactation dairy cattle mobilise their adipose tissue to release lipids, which in turn produces NEFA, which then produces acetyl-co-A, which is converted to ketone bodies without going through the TCA cycle (Ceciliani *et al.,* 2018). Most fat builds up in the liver as a result of oxalo-acetate deficiency, and occasionally this can cause the liver's oxidative capacity to be exceeded. According to Kennedy *et al.* (2020), there is a notion that consuming appropriate levels of propionate in the diet may help reduce the build-up of fat in the liver by facilitating the production of oxalo-acetate. Additionally, it is thought that feeding the milch animals more propionate could enhance their ability to lactate.

In a study different dosages of calcium propionate (100, 200, and 300 g/day) supplementation were found to increase the energy status and nutrient digestibility of dairy cows in the early stages of lactation (Liu *et al.,* 2010). There was a quadratic rise in milk output as calcium propionate concentration increased. Calcium propionate has been used to prevent or cure hypocalcaemia and ketosis in dairy cows, as in rumen it is hydrolyzed into Ca^{2+} and propionic acid (Zhang *et al.,* 2020). The supplementation of calcium propionate in diet was also found to enhance rumen function, accompanied by favourable changes in serum biochemical parameters in dairy cows (Kumar *et al*., 2024). In the early stages of lactation it has been shown that calcium propionate helps reduce hypocalcemia, enhance energy status, and produce more milk (Liu *et al.,* 2010; Martins *et al.,* 2019). The purpose of this study was to investigate how calcium propionate supplementation at varying rates affected the

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milk composition, milk output, and nutrient utilisation in mid-lactating dairy cattle.

Materials and Methods

This experiment of 40 days feeding trial was carried out during 2022 at College of Veterinary Science, Tirupati (India) following approval of protocol by the Institutional Animal Ethics Committee (Ref. No. 281/go/ReBi/S/2000/CPCSEA/CVSc/TPTY/024/Animal Nutrition/ 2022).

Selection of Animals and Treatments

A total of 24 healthy lactating dairy cows (HF × Jersey, Jersey × Sahiwal) were assigned to four treatments with six cows in each group in a completely randomized design with isometric average body weight (399 to 408 kg) and average milk yield (4.43 to 4.72 kg/day). Group T_1 (control diet) was fed *ad libitum* APBN-1 green fodder, concentrate pellet feed and paddy straw with no calcium propionate supplementation. Group T_2, T_3 and T_4 were fed control diet with 60 g, 70 g, and 80 g calcium propionate (The Nipro Technologies Limited, Haryana) per cow/day, respectively. The cows were adapted for stall feeding, dewormed, and vaccinated against Foot and Mouth, and LSD before the commencement of the study. The calcium propionate was mixed with concentrate feed for an hour before feeding in solubilized form for effective mixing, and was fed once in a day (afternoon) throughout the forty days trial period.

Digestibility Trial

After 30 days of feeding, a digestion trial was conducted for seven days following standard method in practice to measure the digestibility of nutrients fed. The representative feed, leftover and faecal samples of individual animals were combined over a week and composite samples were ground to a fine consistency in a laboratory Wiley mill, put through a 2 mm screen, and stored in airtight polythene bags for proximate analysis using the AOAC (2005) method, and the levels of neutral detergent fibre (NDF), acid detergent fibre (ADF) as per Van Soest *et al.* (1991). Digestibility of each nutrient was then determined for each group using standard procedure.

Milk Yield and Milk Composition

The milk yield was recorded thrice a week since the first day of trial, and daily average milk yield was determined for every ten days, *i.e.,* from the 1st to 10th, 11th to 20th, 21st to 30th, and 31st to 40th day for each treatment. The milk samples were analyzed at ten days interval for milk components like fat, solids not fat, protein, total solids and lactose on 10th, 20th, 30th and 40th day of the trial. The milk fat was estimated by using Milkoscreen, FT- infra red ray based machine (high accuracy) developed by the FOSS. The SNF of milk was arrived by the deducting fat % from the total solid content. The lactose was calculated by Lane-Eynon method (volumetric method).

Statistical Analysis

The data were analysed in completely randomized design (CRD) using SPSS (2015) software version 23.0, through generalized linear model and the treatment means were ranked using Duncan's multiple range test with significance at $p<0.05$ according to Snedecor and Cochran (1994).

Results and Discussion

Effect on Digestibility

In lactating dairy cattle fed with or without calcium propionate supplementation, the digestibility coefficients (Table 1) of dry matter ranged from 60.52 to 64.14, organic matter from 61.13 to 64.41, crude protein from 60.91 to 65.54, ether extract from 74.02 to 76.19, crude fibre from 41.90 to 46.63, and NFE from 64.14 to 69.88. The digestibility of CP and CF was significantly higher ($p<0.05$) in all the calcium propionate supplemented groups compared to control, while the digestibility coefficients of DM, OM, and NFE were significantly ($p<0.05$) higher in T_4 followed by T_3 and T_2 as compared to control. The percentage digestibility of the components of the cell wall, namely the NDF and ADF, varied from 65.86 to 68.42 and 54.35 to 58.46 %, respectively, which did not vary statistically among the treatments. Overall, the digestibility of DM, CP, OM, CF were significantly ($p<0.05$) affected with calcium propionate supplementation in the present study.

Table 1: Effect of calcium propionate supplementation on nutrient digestibility (%) in lactating dairy cattle

Nutrient Digestibility	Dietary treatment groups			
	T_1	T_2	T_3	T_4
Dry matter (DM)*	$60.52^{a}\pm0.20$	$62.81^{b}\pm0.43$	$63.19^{bc}\pm0.39$	$64.14^{c}\pm0.35$
Organic matter (OM)*	$61.13^{a}\pm0.36$	$63.67^{b}\pm0.34$	$63.87^{b}\pm0.40$	$64.41^{c}\pm0.39$
Crude protein (CP)*	$60.91^{a}\pm0.43$	$64.92^{b}\pm0.62$	$65.12^{b}\pm0.55$	$65.64^{b}\pm0.66$
Ether extract (EE)	74.02±0.27	75.68 ±0.68	76.19±0.73	74.78±0.52
Crude fibre (CF)*	$41.90^{a}\pm0.39$	$45.76^{b}\pm0.56$	$46.23^{b}\pm0.89$	$46.63^{b}\pm0.98$
Nitrogen free extract (NFE)*	$64.14^{a}\pm0.40$	$68.58^{b}\pm0.40$	$69.08^{bc}\pm0.40$	$69.88^{c}\pm0.21$
Neutral Detergent Fibre (NDF)	65.86±0.43	67.42±0.54	66.64±0.40	68.42±0.32
Acid detergent fibre (ADF)	54.35±0.32	58.42±0.80	57.64±0.90	58.46±0.72

Mean values within the rows bearing different superscripts (a,b,c) differ significantly *($p<0.05$).

Effect on Milk Yield

During the first 10 days of the trial, there was non-significant difference in the average milk production (kg/animal/day) between the treatments. Over the next ten days, the calcium propionate supplemented groups showed a significant ($p<0.05$) increase in daily milk yield, ranging from 4.14 to 4.32 kg. Between the 21st and 30th days, the average milk production (kg/day) varied between 4.19 and 4.45, with the calcium propionate supplemented groups producing significantly ($p<0.01$) more milk than the control group. Between the 31st and 40th day, the average milk production (kg/day) varied between 4.13 and 4.64, with a substantial ($p<0.01$) increase in T_3 and T_4 over the other treatments. During the trial period, the average milk production (kg/animal/day) showed that, in comparison to the control (4.15), T_4 (4.39), T_3 (4.38), and T_2 (4.31) groups had considerably ($p<0.01$) higher milk production (Table 2). The milk samples collected at 10th, 20th, 30th and 40th day from the initiation of trial revealed that as the days progressed the milk production increased. This may be due to improved rumen fermentation, and favourable changes in serum biochemical profile (Kumar *et al*., 2024). Calcium propionate as a source of both calcium and energy can be hydrolysed into Ca^{2+} and propionic acid in the rumen and is used for preventing hypocalcaemia (Zhang *et al*., 2020). The present results agree with Goff *et al.* (1996) and Martins *et al*. (2019) wherein they reported increased milk yield by supplementing calcium propionate. However, they opined that optimal feeding level of calcium propionate must be further investigated.

Effect on DMI and Feed Efficiency for Milk Yield

Dairy cattle fed with or without calcium propionate supplementation, the dry matter intake ranged from 9.98 to 10.45 kg/day, with no discernible variation between the groups. In T_1, T_2, T_3, and T_4, the dry matter intake was 2.48, 2.58, 2.58, and 2.50 % of body weight, respectively. Cows given calcium propionate had a milk output (kg/day) ranging from 4.32 to 4.83, which did not differ significantly. In contrast to the control group, the calcium propionate supplemented groups showed a quantitatively increased milk output. The dry matter intake (kg) per kg milk production ranged from 2.16 to 2.31, which also did not differ substantially among the groups (Table 3).

The results showed that the intake of dry matter increased non-significantly with the level of calcium propionate supplementation (Table 3). It was evident that the dry matter digestibility increased with an increase in the DMI. The findings concurred with McNamara and Valdez (2005), who reported that 125 g/day of calcium propionate supplementation enhanced the dry matter intake of dairy cows by 11% and 13% before and after parturition. Similar to our findings, Villalba and Provenza (1996) also found that lambs supplemented with calcium propionate @ 8.3 g/day increased their feed intake, while @ 16.6 g/day decreased their feed intake. Many authors reported that supplementation of calcium propionate did not affect the dry matter intake in dairy cattle (Zhang *et al*., 2020; Beem, 2003; De Frain *et al*., 2005; Liu *et al*., 2009) and lambs (Lee-Rangel *et al*.,2012), while some authors reported depressed feed intake with supplementation of calcium propionate (Rigout *et al*., 2003). These contradictory and inconsistent results on supplementation of calcium propionate on DMI may be due to the nutritional level of the basic diets and the quantum of calcium propionate supplemented.

After calving, large amount of glucose is required to meet the increasing milk production in dairy cows (Liu *et al*., 2010). Propionate produced from ruminal fermentation is the greatest contributor ranging from 60-74% for gluconeogenesis. Further this glucose is the precursor for

Table 2: Effect of calcium propionate supplementation on average daily milk yield (kg/animal/day) for every 10 days interval in lactating dairy cattle

Time interval	Dietary treatment groups			
	T_1	T_2	T_3	T_4
1 to 10 days	4.10±0.06	4.15±0.04	4.15±0.02	4.13±0.06
11 to 20 days*	4.14^a±0.06	4.27^b±0.02	4.31^b±0.02	4.32^b±0.04
21 to 30 days**	4.19^a±0.04	4.36^b±0.05	4.44^b±0.03	4.45^b±0.04
31 to 40 days **	4.14^a±0.05	4.47^b±0.04	4.61^c±0.04	4.64^c±0.03
Overall average**	**4.15^a±0.05**	**4.31^b±0.02**	**4.38^b±0.02**	**4.39^b±0.03**

Mean values within the rows bearing different superscripts (a,b,c) differ significantly *($p<0.05$).

Table 3: Effect of calcium propionate supplementation on average daily milk yield (kg/animal/day) in lactating dairy cattle

Group	Avg B.Wt.	DMI (kg)	DMI as % Body weight	MY (kg)	FCR (DMI:MY)	FE (MY:DMI)
T_1	402.50	9.98±0.50	2.48±0.16	4.32±0.37	2.31±0.23	0.43±0.13
T_2	401.58	10.34±0.22	2.58±0.09	4.56±0.31	2.27±0.14	0.44±0.09
T_3	411.16	10.27±0.43	2.50±0.20	4.49±0.42	2.29±0.29	0.43±0.06
T_4	408.25	10.45±0.39	2.56±0.04	4.83±0.26	2.16±0.17	0.46±0.08

Avg B.Wt.: Average body weight DMI**:** Dry matter intake MY: Milk yield, FCR: feed conversion ratio FE: Feed efficiency. None of the parameters differed significantly between groups.

Table 4: Effect of calcium propionate supplementation on milk composition during the experimental period

Component (%)	Dietary treatment groups				P value
	T_1	T_2	T_3	T_4	
10th day of trial period					
Fat	4.41±0.19	4.56±0.27	4.58±0.22	4.56±0.21	NS
Solids not fat	8.79±0.23	8.98±0.12	8.84±0.21	8.95±0.13	NS
Protein	4.00±0.08	4.01±0.04	4.04±0.16	4.03±0.10	NS
Total solids	13.57±0.11	13.67±0.26	13.69±0.35	13.72±0.27	NS
Lactose	4.03±0.14	4.06±0.23	4.05±0.12	4.08±0.16	NS
20th day of trial period					
Fat	4.56±0.23	4.42±0.17	4.53±0.10	4.68±0.08	NS
Solids not fat	8.83±0.37	8.95±0.26	8.96±0.32	9.02±0.26	NS
Protein	4.08±0.23	4.08±0.03	4.04±0.06	4.03±0.02	NS
Total solids	13.59±0.26	13.72±0.15	13.74±0.24	13.81±0.15	NS
Lactose	4.05±0.22	4.01±0.14	4.03±0.21	4.04±0.32	NS
30th day of trial period					
Fat	4.58±0.11	4.39±0.21	4.44±0.02	4.32±0.09	NS
Solids not fat	8.85±0.21	8.98±0.33	9.02±0.14	9.04±0.18	NS
Protein	4.02±0.30	4.03±0.13	4.03±0.06	4.07±0.22	NS
Total solids	13.52±0.18	13.82±0.25	13.70±0.10	13.72±0.24	NS
Lactose	4.08±0.21	4.06±0.13	4.03±0.34	4.06±0.17	NS
40th day of trial period					
Fat	4.38±0.18	4.42±0.11	4.46±0.26	4.34±0.08	NS
Solids not fat	8.83±0.09	8.95±0.14	9.04±0.11	9.02±0.23	NS
Protein	4.02±0.13	4.01±0.16	4.05±0.10	4.04±0.24	NS
Total solids	13.52±0.19	13.74±0.05	13.74±0.23	13.79±0.08	NS
Lactose	4.05±0.12	4.01±0.27	4.04±0.31	4.08±0.14	NS

Each value is mean of six observations, NS-Non significant.

the synthesis of lactose, which is the primary osmoregulator of milk synthesis (Reynolds *et al*., 2003). Liu *et al.* (2010) reported that feeding different levels of calcium propionate to the Holstein cows did not affect DMI or milk yield in first 63 days of lactation. The results of these studies may be related to the quantum of supplementation of calcium propionate, method of basal diet feeding, body condition and physiological status of the experimental animals. In the present study as the dosage of calcium propionate and period of supplementation prolonged, lactation performance was improved and the reason could be attributed to that propionate is a primary glucose precursor in dairy cows and contributes to the synthesis of oxaloacetate (Duplessis *et al.*, 2017) and (Kennedy *et al*., 2020).

Milk Composition

Analysis of milk components (%) such as fat, SNF, protein, total solids, and lactose showed that there was no discernible difference between the treatments at any point during the trial period. In comparison to the control group, a numerical rise in the SNF % was noted in all groups supplemented with calcium propionate across all time intervals. There is no discernible change in the components of milk, suggesting that calcium propionate has no influence on the composition of milk, although more milk was produced (Table 4). These results concurred well with McNamara and Valdez (2005), wherein they also reported that supplementation of calcium propionate did not change milk fat, protein, lactose and MUN significantly, though calcium propionate @ 125 g/day tended to decrease milk fat, lactose and protein.

Conclusion

Supplementation of calcium propionate in the diet of lactating crossbred cows showed significant changes in the digestibility of nutrients with a corresponding increase in the milk yield, though there was no significant variation in the milk composition. However, as the dose of the calcium propionate increased the effect was much more significant. Supplementation also affected the DMI per kg milk produced.

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