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RESEARCH ARTICLE

Effect of feeding total mixed ration supplemented with sodium bicarbonate and magnesium oxide on milk yield, milk composition and manure score in early lactating dairy cattle

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Abstract: The study was conducted on 120 crossbred early lactating dairy cows to compare the effect of feeding Total Mixed Ration (TMR) supplemented with or without buffers i.e. sodium bicarbonate ($NaHCO_3$) and magnesium oxide (MgO) on milk yield, milk composition (milk fat percentage, solid not fat) and manure score. Animals were selected from 8 dairy farms in the Hoshiarpur district during the July-August period of 2021 and 2022, they were divided into 3 treatment groups (T1, T2 and T3) at each farm with 5 cows in each group, and 8 replications. During the 60 days trial, each cow in the treatment group T3 was fed a diet consisting of TMR along with a buffer prepared on farm using $NaHCO_3$ and MgO in the ratio of 3:1 and mixed in concentrate ration @ 1kg/ quintal. Each cow in group T2 was fed a diet that contained only TMR. In T1group, no TMR and buffers were fed to the cows, only routinely farmers practiced was followed. The TMR was offered *ad libitum* indoors in T2 and T3 treatment groups at 09:00 and 18:00 h. Milk yield, milk fat percentage, Solid Not Fat (SNF) and manure score were recorded on days 0 and 60 of the 60-day trial. SPSS software was used for statistical data analysis. The results showed that feeding TMR to early lactating dairy cows with or without the addition of dietary $NaHCO_3$ and MgO increased milk yield, milk fat percentage and SNF concentration significantly ($p>0.05$). However, there was no significant ($p>0.05$) difference in milk yield between the T2 and T3 treatment groups. Additionally, cow dung was observed using the consistency and digestion methods. Score 2 was noted in T1 treatment group, whereas Score 3 was noted in the T2 and T3 treatment groups under the consistency method. Using the digestion method, Score 2 was seen in the T1 treatment group, whereas Score 1 was seen in the T2 and T3 treatment groups. Implementing TMR in dairy cattle is efficient and effective, particularly in terms of milk production and milk composition, as well as improving manure score, which is an indicator of feed digestibility.

Keywords: Dairy cattle, TMR, Buffer, Milk yield, Milk composition, Manure score

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Introduction

Dairy cattle have been producing more milk over the years, so in an effort to meet the nutritional demands of the cows, the energy density of the ration has also been rising. In order to meet the increased milk production of cross-bred dairy cows in India, feeding practices changed from roughage to a high concentrate diet in the dairy ration. Feeding high concentrate diets results in sub-acute ruminal acidosis (SARA), which lowers the pH of the rumen (Hossain 2020), modifies the rumen microflora (Hashemi and Tavakolinasab 2023), alters rumination (Muthusamy et al. 2021), and lowers the percentage of milk fat (Musa and Pandey 2017). It is generally advised to include buffers in dairy rations when depression of milk fat is an issue (Razzaghi et al. 2020). In most parts of the world, it is common practice to add sodium bicarbonate to the diets of high-yielding dairy cows as a rumen buffer (Neville et al. 2019). Sodium bicarbonate supplementation to the diet raises milk production and milk fat percentage (Musa and Pandey 2017) and stabilizes the pH of the rumen (Kumar et al. 2024). According to various reports (Leno et al. 2017; Tebbe et al. 2018), the efficiency of MgO sources in elevating the ruminal pH and fostering improvements in milk yield and milk fat varies. However, Bach et al. (2018) showed that a magnesium-based product is more effective at neutralizing rumen pH and preserving milk fat content compared to sodium bicarbonate when cows are given an extra 3 kg/d of barley in their diet. Studies have been done to supplement magnesium oxide alone (Neville et al. 2019; Razzaghi et al. 2020; Li et al. 2022), sodium bicarbonate (Musa and Pandey 2017; Musa and Choudhary 2018; Muthusamy et al. 2021), or both in an effort to manipulate the rumen for higher milk production (Bach et al. 2018; Agustinho et al. 2022). A beneficial

effect was demonstrated by adding either 1.5% $NaHCO_3$ alone or in combination with 0.8% MgO to the total ration (40% corn silage and 60% concentrate) during early lactation (Erdman et al. 1980).

Enhancing the performance of dairy cattle is the primary goal of preparing a TMR (Total Mixed Ration). The recent rise in cattle fed TMR has contributed to an increase in milk production worldwide (Schingoethe 2017). Feeding TMR reduces feed selection and sorting, provides adequate nutrition and increases feed utilization efficiency (Mendoza et al. 2016; Beigh et al. 2017; Premarathne and Samarasinghe 2020). As TMR feeding systems are frequently utilized during the non-grazing season, many dairy producers own the necessary equipment and have expertise using them. TMR can be prepared efficiently using various forage species, crop residues and industrial byproducts (Karunanayaka et al. 2022). Additionally, TMR feeding lowered labour costs and can be formulated as per individual animal requirements (Schingoethe 2017). Moreover, it enhanced feed intake, digestibility, and rumen microbial activity, all of which led to higher cow productivity (Karunanayaka et al. 2022). A better milk fatty acid profile can be achieved through the grazing component, and supplementing with TMR could help produce high yields of milk with enhanced protein and fat contents. According to Mohammad et al. (2017) and Cameron et al. (2018), the TMR feeding produced a higher milk yield than regular feeding. Compared to cattle fed TMR, grazing dairy cattle produced less milk (Karunanayaka et al. 2022).

Manure scoring (also called dung or fecal scoring) is a simple method of assessing the condition of a cow's digestive system, ranging from signs of acidosis to excess/insufficient protein in the diet to mycotoxins or disease. According to Musa and Choudhary (2018), this tool aids in assessing the degree of digestibility of cow feed, the appropriateness of water intake, and the nutrient balance of the ration, which includes protein, fiber, and carbohydrates. The ideal manure score fluctuates during lactation due to rumen function changes and dietary modifications (Petrovski et al. 2022). Cows should normally have a manure score of 2.0–2.5 in the first few days of lactation, 2.5–3.0 from 7 to 180 days in milk, and 3.0–3.5 in the last few days of lactation. The mean manure score of early-period dry cows should be 3.0-4.0, while the later dry period should be 2.5-3.5-4.0 (Petrovski et al. 2022). Adverse changes in manure scores may suggest nutritional imbalances in the ration, poor mixing, improper food sorting at the feeding area, or intolerable competition during feeding (Petrovski et al. 2022).

The dairy industry now routinely includes $NaHCO_3$ in diets, either with or without additional MgO. Complex mixtures of buffers, alkalis, and other substances known to influence milk composition or production are also commercially available. Moreover, only few studies available in literature that analyze the effects of TMR combined with $NaHCO_3$ and MgO on milk production performance (Arambel et al. 1988; Bach et al. 2018) and manure scoring in cow. Thus, the goal of this research was to assess how feeding TMR with or without $NaHCO_3$ and MgO supplements affected the performance of early lactation cows.

Materials and Methods

Eight villages were included in the study: Haveli, Motian, Mahilpur from the Mahilpur block; Chak Narial and Jhonjowal from the Garhshankar block; Raipur from the Hoshiarpur-I block; and Mehtiana from the Hoshiarpur-II block of the district Hoshiarpur. Data on milk yield, milk constituent (milk fat percentage, solid not fat) and manure score were collected twice from each animal during the period from July to August, 2021 and 2022. The study area is located in the following geographic coordinate systems: Latitude: 31.3630 ºE, Longitude: 76.0363 ºN; Latitude: 31.2175 ºE, Longitude: 76.1407 ºN; Latitude: 31.510 ºE, Longitude: 75.770 ºN; Latitude: 31.3708 ºN, Longitude: 75.8171 ºE of Mahilpur; Garhshankar; Hoshiarpur-I and Hoshiarpur-II block, respectively, with an average annual rainfall of 630 mm. During the summer, the average daily temperature was 39.3 ºC with a relative humidity of 62.3%. The majority of the dairy farms in the Hoshiarpur district used tie-up stall feeding.

Experimental design

This study uses a Completely Randomized Design (CRD) for its experiment. The study involved the selection of 120 crossbred dairy cows from 8 dairy farms (15 cows from each farm). At each farm, the selected cows were then divided into three treatment groups i.e., T1, T2, and T3 with 5 cows in each group, and 8 replications. All animals were in the early lactation stage and the mean milk production was 14.1±0.16 kg/day/animal in the month prior to the start of the experiment. All cows were kept under identical management conditions to checkmate error due to environment variations.

Experimental diet

During the 60 days trial, each cow in the treatment group T3 was fed a diet consisting of TMR along with buffer made on the farm using a 3:1 ratio of $NaHCO_3$ to MgO and mixed in concentrate ration @1kg/quintal. Each cow in the treatment group T2 was fed a diet that contained only TMR. The cows in the treatment group T1 were not given TMR and buffers; instead, the farmers merely followed their regular practices. The treatment groups T2 and T3 received the TMR indoors, *ad libitum*. All of the animals had access to plenty of fresh, clean water to drink during the trial. Prior to the start of the trials, the research team provided guidance to farmers and farm workers regarding the treatment protocol.

Based on NRC (2001) feeding guidelines, lactating cattle in treatment groups (T2 and T3) were fed a TMR that included roughage and concentrate mixture in a 50:50 ratio, respectively, to meet their nutritional needs (Table 1). On the other hand,

concentrate mixture, green fodder, and dry fodder were fed to the treatment group (T1) and the control groups (T1, T2, and T3) in accordance with routine farmer practices. The composition of used concentrate mixture presented in Table 2. Each day, the TMR was manually mixed separately for every treatment group, containing 63.82% Total Digestible Nutrients (TDN) and 12.41% Crude Protein (CP). The TMR was offered at 09:00 and 18:00 h.

Tests and procedures

With the exception of 10 days for standardization and acceptance of the test ration in accordance with the treatment combinations used on the experimental animals, the trial lasted 60 days. On day 0 (control group) and day 60 (treatment group) of the feeding trial, 200 milliliters of fresh milk were taken twice a day (morning and evening) from each selected animal. Lactoscan was used to analyze each sample for milk components, such as milk fat percentage and SNF. The research team regularly monitored and recorded the milk yield (L/day).

Manure scoring

Manure scoring was also noted during morning milking on days 0 and 60 of the experimental period, following a 10-day adaptation period. Based on a 5-category scale (Table 3), the consistency and digestion of the manure on all the floors was evaluated in

Table 1: Ingredients and nutritive value of TMR (% Dry Matter Basis) fed during the experimental period to the treatment groups

Ingredients	Quantity (%)	
	T2 group	T3 group
Maize Fodder	33.0	33.0
Wheat Straw	17.0	17.0
Ground Yellow Maize	17.0	17.0
Soybean Meal	5.00	5.00
Groundnut Cake	4.50	4.00
Deoiled Mustard Oil Cake	6.40	6.40
Wheat Bran	6.50	6.50
Deoiled Rice bran	5.00	4.50
Molasses	2.50	2.50
Buffer	-	1.00*
Bypass Fat	1.50	1.50
Yeast	0.05	0.05
Methionine	0.05	0.05
Mineral Mixture	1.00	1.00
Common Salt	0.50	0.50
Chemical composition (%)		
Crude Protein	12.68	12.41
Total Digestible Nutrient	64.46	63.82

*Buffer ($NaHCO_3$ and MgO in a 3:1 ratio)

Table 2: Composition of concentrate mixture

Ingredients	Quantity (%)
Ground Yellow Maize	34
Ground Nut Cake	9
Soybean Meal	10
De Oiled Mustard Oil Cake (Expeller Extracted)	12.8
Wheat Bran	13
Deoiled Rice Bran	10
Molasses	5.0
Bypass Fat	3.0
Yeast	0.10
Methionine	0.10
Mineral Mixture	2
Common Salt	1

accordance with Hauge et al. (2012), Musa and Choudhary (2018) and Petrovski et al. (2022).

Statistical analysis

The statistical analysis was performed with Statistical Package for Social Sciences (SPSS) version 20.0 statistical software for Windows (version 16.0; Microsoft). The numerical data of each parameter (milk yield, fat percentage and SNF) was tested for normality. The average of the two values for each parameter was used. Descriptive statistics were calculated for each of the parameters and data were presented as mean and standard error (S.E.) of mean. The following model was used to analyze data on milk yield, milk fat percentage, and SNF using the one-way analysis of variance (ANOVA) technique:

$Y_{ij} = \mu + T_i + \varepsilon_{ij}$

Where, Y_{ij} is each observation (milk yield, fat percentage and SNF); μ represents the total mean; T_i is the effect of i^{th} treatment (i = T1, T2 and T3) and $[_{ij}$ is the residual error.

Tukey's test was used to compare the treatments, and differences were considered as statistically significant at $p>0.05$.

Results and Discussion

Effect on milk yield

The milk yield values for control (day 0) and treatment (day 60) groups are presented in Table 4 as mean and standard error (SE). In T2 and T3 treatment groups, significant ($p>0.05$) increase was observed in milk yield at day 60 of the trial. In contrast to the T3 treatment group, the T2 treatment group exhibits a non-significantly ($p>0.05$) higher milk yield. In the T1 group, there was no significant ($p>0.05$) difference in milk yield at day 0 or day 60 of the experiment. Furthermore, a statistical comparison in Table 4 revealed no discernible difference between the control groups (T1, T2, and T3).

As per the findings of Mohammad et al. (2017) and Cameron et al. (2018), TMR feeding increases milk yield in dairy cows more than normal feeding does. These findings are consistent with the findings of the current study. TMR feeding to dairy cows, on the other hand, was found to have no effect on milk production by Morales-Almaráz et al. (2010). The present study's findings are corroborated by studies conducted by English et al. (1983) and Arambel et al. (1988) which found that adding buffers ($NaHCO_3$ and MgO) to TMR did not significantly alter milk yield in dairy

Table 3: Manure scoring chart

Score	Consistency	Digestion (feeling by hand)
1	This manure is very liquid with the consistency of pra soup. The manure may actually "arc" from the rump of the cow. Excess protein or starch, too much mineral, or lack of fibre , can lead to this score. Excess urea in the hind-gut can create an osmotic gradient drawing water into the manure. Cow with diarrhoea will be in this category.	Manure feels like a creamy emulsion and is homogeneous. There are no visible undigested food particles.
2	Manure appears runny and does not form a distinct pile. It will measure less than 2.5 cm in height and splatters when it hits the ground or concrete. Cows on lush pasture will commonly have this type of manure. Low fibre or a lack of functio nal fibre can also lead to this manure score.	Manure feels like a creamy emulsion and is homogeneous. A few undigested food particles are visible.
3	This is the optical score! The manure has a porridge -like appearance, will stack up 4 to 5cm, have several concentric rings, a small depression or dimple in the middle, make a plopping sound when it hits concrete floors, and it will stick to the toe of your shoe.	Manure doesn't feel homogeneous. Some undigested particles are visible. After squeezing in the han d, some undigested fibres will stick to your fingers.
4	The manure is thicker, will stick to your shoe, and stacks up over 5 cm. Dry cows and older heifers may have this type of manure (this may reflect feeding with low quality forages and/or a shortage of protein). Adding more grain or protein can lower this manure score.	Bigger undigested food particles are clearly visible. A ball of undigested food will remain after squeezing the dung in your hand.
5	This manure appears as firm faecal balls. Feeding a straw based diet or dehydration would contribute to this score. Cows with a digestive blockage may exhibit this score.	Bigger food particles are tangible in manure. Undigested components of the feed ration are clearly recognizable.

Table 4: Effect of treatments on milk parameters in crossbred cows (Mean±S.E.)

Parameter	Control Group (Day 0)			Treatment Group (Day 60)		
	T1 (n=40)	T2 (n=40)	T3 (n=40)	T1 (n=40)	T2 (n=40)	T3 (n=40)
Milk Yield (L/day)	14.2±0.15^{a}	14.1±0.16^{a}	14.0±0.16^{a}	14.1±0.15^{a}	15.7±0.11^{b*}	15.4±0.10^{b*}
Milk Fat (%)	3.79±0.02^{a}	3.81±0.02^{a}	3.81±0.02^{a}	3.80±0.02^{a}	4.24±0.02^{b*}	4.31±0.03^{b*}
Milk SNF (%)	7.84±0.02^{a}	7.86±0.02^{a}	7.84±0.02^{a}	7.81±0.02^{a}	8.02±0.02^{b*}	8.06±0.02^{b*}

Values with similar alphabets as superscripts in a row do not differ significantly ($p>0.05$), separately for control and treatment groups.
*Differ significantly ($p>0.05$) from the respective values of the control group.

cows during the early stages of lactation. According to Strokes et al. (1986), supplementing with buffers ($NaHCO_3$ and MgO) had no effect on the intake of DM, milk yield and milk composition. The present study's findings conflict with those of Erdman et al. (1980) and Teh et al. (1985), who found that feeding dairy cows TMR during the early stages of lactation resulted in a significant increase in milk production.

Effect on milk fat percentage and SNF

The milk fat percentage and SNF values for control (day 0) and treatment (day 60) groups are presented in Table 4 as mean and standard error (S.E.). In this study, on the 60th day of the experimental period, a significant ($p>0.05$) increase in the levels of milk components (milk fat percentage and SNF) was observed in the T2 and T3 treatment groups compared to 0 day of the trial. Nevertheless, compared to the T2 treatment group, the milk fat percentage and SNF of the T3 treatment group are non-significantly ($p>0.05$) higher. Between day 0 and day 60 of the experimental period, there was no discernible change in the milk fat percentage and SNF in the T1 group (Table 4). Additionally, statistical analysis showed that there was no significant ($p>0.05$) difference in milk fat percentage and SNF between the T1, T2, and T3 control groups in Table 4.

Similar results were obtained by Gaafar et al. (2010), who found that cows fed TMR had high levels of milk fat, lactose, solid non-fat, and total solids. However, Teshome et al. (2017) found that feeding pasture or TMR had no effect on the amount of fat, protein, lactose, ash and total solids in milk. Consistent with the current results, studies by English et al. (1983), Stokes et al. (1986), and Arambel et al. (1988) found that feeding dairy cows with similar diets and at a similar stage of lactation, supplementing with $NaHCO_3$ and MgO did not significantly affect the components of milk (milk fat percentage and SNF). In contrast to Erdman's et al. (1982) findings, which showed that adding dietary $NaHCO_3$, MgO, and $NaHCO_3$ plus MgO increased milk fat percentage significantly, the current study's findings show that the combination of $NaHCO_3$ and MgO was more effective than either $NaHCO_3$ or MgO alone. Low milk fat tests were corrected by adding $NaHCO_3$ and MgO, either separately or in combination, according to reports from Erdman et al. (1980).

Effect on manure score

1. Scoring of manure by consistency

The present experiment had observed Score 3 in the treatment groups T2 and T3. When the manure hits the floors, it makes a plopping sound and sticks to the toe of your shoe. It also has a porridge-like appearance, stacks up to 5 cm, and has several concentric rings and a small depression or dimple in the middle (Table 3). In line with the current study's findings, Musa and Choudhary (2018) found Score 3 when $NaHCO_3$ was supplemented through diet. In contrast, Score 2 was noted in the T1 treatment group and the T1, T2, and T3 control groups; in these cases, the manure looks runny and does not form a distinct pile (Table 3). When it hits the ground, it splatters and is less than 2.5 cm tall. Petrovski et al. (2022) state that cattle's overall health, rumen fermentation status, and digestive function can all be determined by observing their feces, which are especially readily acclimated to TMR feeding.

2. Scoring of manure by digestion (feeling by hand)

The current study found that the treatment groups T2 and T3 had Score 1 under this category of manure scoring. The manure has a uniform texture and feels like a creamy emulsion. No visible remnants of undigested food are present (Table 3). Prayitno et al. (2017) supported our findings by showing that digestibility increased and feed intake decreased with reduced chewing time with the TMR. In contrast, Score 2 was noted in the T1 treatment group and the T1, T2, and T3 control groups. Manure is homogenous and has a creamy emulsion-like texture. There are a few visible pieces of undigested food (Table 3). According to Karunanayaka et al. 2022, the feed intake, digestion, and milk production of early lactation cows were impacted by the particle size of the TMR.

Conclusion

The results suggest that TMR feeding, either alone or supplemented with a 1% buffer consisting of $NaHCO_3$ and MgO in a 3:1 ratio significantly ($p>0.05$) increased milk yield, milk fat percentage and SNF content, indicating better milk quality. Additionally, it improves manure score (Score 3 under consistency method and Score 1 under digestion method) which suggests better digestive health or nutrient utilization by dairy cattle. Therefore, feeding TMR without addition of buffers to early lactating dairy cattle producing up to 15 kg of milk could be a more economical option for improving productivity.

Author Contribution Statement

The authors confirm contribution to this paper as follows: Kanwarpal Singh Dhillon coordinated the study's conception and design, as well as the data collection, analysis, and interpretation of results. Ravi Prakash Pal participated in preparing draft manuscript. Both the authors reviewed the results and approved the final version of the manuscript.

Ethical approval

The Director of Extension Education at Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana approved this study at the meeting on the vetting of On-Farm Trials of Krishi Vigyan Kendra's (vide no. DEE/2767; dated: 19/03/2021). All pertinent institutional, national, and international guidelines for the care and use of animals were followed.

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Conflicts of Interest

The authors of this article declare that they have no conflicts of interest.

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