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Impact of nutritional supplementation on milk yield and quality in dairy cows

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Abstract

This study evaluated the effect of targeted nutritional supplementation on milk yield, milk composition, and economic returns in crossbred lactating cows (Holstein Friesian × Sahiwal). Thirty healthy cows (4-7 years) were randomly allotted into two groups (n = 15) and monitored for 90 days, including a 10-day adaptation period. The control group received a basal ration of green fodder, dry roughage, and concentrate mixture as per NRC (2001) guidelines, while the treatment group received the same diet supplemented with bypass protein (250 g/cow/day), chelated minerals (50 g/cow/day), and vitamins A, D₃, and E. Milk yield was recorded daily, and compositional traits—including fat, protein, solids-not-fat (SNF), lactose, and total solids—were analyzed weekly using a Lactoscan analyzer. Feed ingredients were evaluated for proximate composition. Data were analyzed using one-way ANOVA ($p < 0.05$). Nutritional supplementation significantly improved milk performance, with the treatment group producing 18.2% more milk (16.2 vs. 13.7 L/day). Milk composition also improved, including increases in fat (3.8% to 4.2%), protein (3.2% to 3.5%), SNF (8.5% to 8.8%), total solids (12.3% to 13.0%), and lactose (4.6% to 4.8%). Although the treatment increased feed cost slightly (₹210 vs. ₹190/cow/day), net profit was 22.7% higher (₹405.6 vs. ₹330.6/cow/day) due to improvements in milk yield and quality. The findings indicate that targeted supplementation strategies can substantially enhance milk production and profitability under tropical dairy farming conditions, although cost may influence adoption by smallholders.

Keywords: Nutritional supplementation, milk yield, milk composition, crossbred cows

Introduction

Dairy farming is a crucial component of global agriculture and food security, especially in developing countries like India, which contributes over 20% of global milk production (FAO, 2023; DAHD, 2023) [3, 2]. Crossbred cows such as Holstein Friesian × Sahiwal are central to this productivity because of their adaptability and high milk yield potential (Kumar *et al.*, 2019) [6]. However, achieving optimal milk production and maintaining quality remain challenges, largely due to nutritional deficiencies that restrict lactational performance (NRC, 2001) [11]. Lactating cows require balanced nutrients—including energy, protein, minerals, and vitamins—to support milk synthesis and overall health (Goff, 2018) [5]. Although basal diets of green fodder, dry roughage, and concentrate provide essential nutrition, they often lack specific components needed to optimize yield and composition (McDonald *et al.*, 2011) [8]. Targeted supplementation can bridge these gaps. Bypass protein enhances amino acid availability for milk protein synthesis (Santos *et al.*, 1998) [14], while chelated minerals offer superior bioavailability, supporting metabolic functions and milk fat synthesis (Spears, 2003; Overton & Waldron, 2004) [17, 12]. Vitamins A, D₃, and E contribute to epithelial integrity, calcium metabolism, oxidative balance, and overall milk quality (Weiss, 2017) [18].

Improving milk composition—fat, protein, SNF, and lactose—is economically important because Indian milk pricing is strongly influenced by fat and SNF content (NDDB, 2022) [10]. Suboptimal nutrition can reduce these components, lowering market returns (Palmquist *et al.*, 1993) [13]. Previous studies indicate that supplementation with bypass protein and minerals can increase milk yield by 1-3 L/day and improve fat by 0.2-0.5% in crossbred cows (Sharma *et al.*, 2020) [15], translating into higher profitability despite increased feed costs (Lean *et al.*, 2018; Moran, 2005) [7, 9]. However, adoption of supplementation among smallholder farmers remains limited due to cost concerns, lack of awareness, and variation in animal response depending on breed, diet, and lactation stage (Moran, 2005; Santos *et al.*,

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1998) [9, 14]. Comprehensive studies integrating bypass protein, chelated minerals, and vitamins under Indian farm conditions are still scarce.

To address this gap, the present study evaluates the combined effects of bypass protein, chelated minerals, and vitamins A, D₃, and E on milk yield, composition, and economic returns in crossbred lactating cows under controlled farm conditions. The findings aim to support improved feeding strategies, enhance productivity, and strengthen the sustainability of dairy systems in tropical environments.

Materials and Methods

a. Experimental Animals and Design

The experiment was conducted at the University Dairy Research Farm using 30 healthy lactating crossbred cows (Holstein Friesian × Sahiwal), aged 4-7 years and in their second to fourth lactation. Cows were selected based on similar body condition scores (3.0-3.5/5) and initial milk yield (12-14 L/day) to minimize variability (Ferguson *et al.*, 1994). Animals were housed in a well-ventilated, open-sided barn with ad-libitum access to clean water and managed under standard dairy husbandry practices. Cows were randomly assigned into two groups (n = 15) in a completely randomized design as given.

Group I (Control): Fed a basal diet comprising green fodder (20 kg/cow/day; maize and berseem), dry roughage (5 kg/cow/day; wheat straw), and a concentrate mixture (6 kg/cow/day) formulated according to NRC (2001) [11] recommendations (18% CP; 70% TDN).

Group II (Treatment): Received the same basal diet supplemented with:

250 g/cow/day bypass protein (formaldehyde-treated soybean meal, 40% CP)

50 g/cow/day chelated mineral mixture (Zn, Cu, Mn, Se in organic form)

Vitamin premix providing 100,000 IU vitamin A, 20,000 IU vitamin D₃, and 50 mg vitamin E.

Supplement doses were selected based on established efficacy in improving milk production and composition (Santos *et al.*, 1998; Weiss, 2017) [14, 18].

b. Experimental Duration and Sampling

The study lasted 90 days, including a 10-day adaptation period to stabilize feed intake and milk production (McDonald *et al.*, 2011) [8]. Milk yield was recorded daily at morning (06:00) and evening (18:00) milkings using calibrated electronic scales. Weekly composite milk samples (100 mL/cow) were collected, pooled from both milkings, and stored at 4 °C with potassium dichromate as preservative. Daily feed intake and refusal were recorded to ensure uniform consumption. Body weight was measured biweekly to monitor changes in condition.

c. Laboratory Analysis

Milk samples were analyzed for fat, protein, SNF, lactose, and total solids using a Lactoscan analyzer (Milkotronic Ltd., Bulgaria), with periodic validation using AOAC (2016) [1] methods. Feed samples were analyzed for dry matter, crude protein, ether extract, crude fiber, and ash following AOAC (2016) [1] procedures. The bypass protein fraction was confirmed using *in vitro* rumen degradation

assays to ensure 60-70% rumen undegradability (Santos *et al.*, 1998) [14].

d. Statistical Analysis

Milk yield, milk composition, and economic parameters were analyzed using one-way ANOVA in SPSS v25.0 (IBM Corp.). Weekly yield data were analyzed using repeated-measures ANOVA to account for temporal effects. Differences between means were considered significant at $p < 0.05$, and Tukey's test was used for post-hoc comparisons (Snedecor & Cochran, 1989) [16].

Results and Discussion

a. Milk Yield

Supplementation significantly increased milk yield compared to the control ($p < 0.05$). The treatment group produced an average of 16.2 L/day, compared to 13.7 L/day in the control group. Weekly trends (Table 1) show a steady rise in yield from 13.1 to 16.2 L/day in the treatment group, stabilizing by Week 9, whereas the control group exhibited minimal fluctuations (12.8-13.8 L/day).

Table 1: Effect of Nutritional Supplementation on Milk Yield Over 12 Weeks

Week	Control Group (L/day)	Treatment Group (L/day)
1	12.8	13.1
2	12.9	13.6
3	13	14.2
4	13.3	14.8
5	13.5	15.2
6	13.7	15.6
7	13.8	15.8
8	13.7	16
9	13.6	16.2
10	13.5	16.3
11	13.4	16.2
12	13.3	16.2

In control group, the milk yield increases slightly from 12.8 to 13.8 L/day by Week 7, then a gradual decline follows, ending at 13.3 L/day by Week 12. The overall net gain across the trial was +0.5 L/day.

In treatment Group, the milk yield rises steadily from 13.1 to 16.2 L/day, peaking at 16.3 L/day in Week 10, then stabilizes around 16.2 L/day thereafter. The overall net gain was +3.1 L/day. In comparative weekly difference, the treatment group consistently outperforms the control group as shown in table 2.

Table 2: Comparative weekly difference

Week	Difference (Treatment-Control)
Week 1	+0.3 L/day
Week 6	+1.9 L/day
Week 10	+2.8 L/day
Week 12	+2.9 L/day

Percentage Improvement: The mean Control Yield was 13.5 L/day and Mean Treatment Yield was 15.6 L/day, the percentage improvement was found as 15.5% ($15.6 - 13.5 / 13.5 \times 100$). So supplementation results in approximately 15-16% higher milk yield.

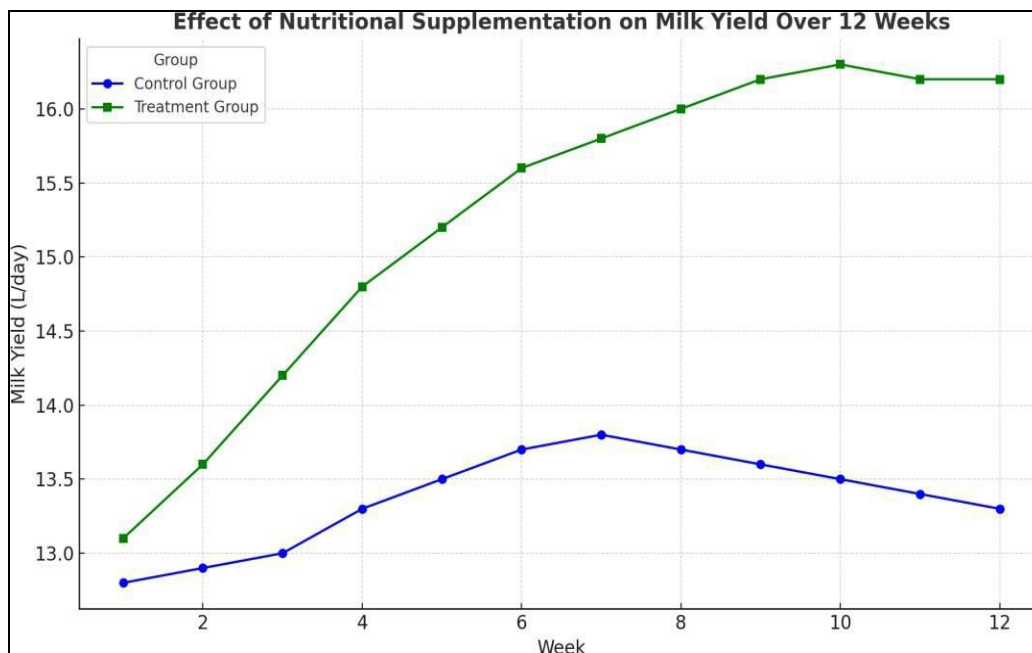


Fig 1: Effect of Nutritional Supplementation on Milk Yield

The table 1 and 2 and Fig 1 clearly demonstrate the consistent and substantial improvement in milk yield among cows receiving nutritional supplementation. These findings align with earlier reports that bypass protein increases amino acid availability, improving milk synthesis (Santos *et al.*, 1998) [14], while chelated minerals enhance enzymatic and metabolic processes that support higher yield (Spears, 2003) [17]. Vitamins A, D₃, and E may have contributed to improved metabolic efficiency and udder health (Weiss, 2017) [18]. The observed lactation curve—with stabilization after Week 9—matches the expected trend for mid-lactation cows (NRC, 2001) [11].

b. Milk Composition

Supplementation significantly improved all measured compositional traits ($p < 0.05$). Milk fat increased from 3.8% to 4.2%, protein from 3.2% to 3.5%, SNF from 8.5% to 8.8%, and lactose from 4.6% to 4.8%. Total solids rose from 12.3% to 13.0%.

Table 2: Comparison of Milk Composition Parameters Between Control and Treatment Groups

Parameter	Control Group	Treatment Group	% Increase
Milk Fat (%)	3.8	4.2	10.5
Milk Protein (%)	3.2	3.5	9.4
Solid-not-Fat (SNF, %)	8.5	8.8	3.5
Total Solids (%)	12.3	13	5.7
Lactose (%)	4.6	4.8	4.3

Increases in milk fat may be attributed to improved rumen fermentation and enhanced acetate production facilitated by chelated minerals (Palmquist *et al.*, 1993) [13]. Higher milk protein reflects increased metabolizable amino acids supplied through bypass protein (NRC, 2001) [11]. Improvements in SNF and lactose indicate enhanced carbohydrate metabolism and nutrient utilization. Similar trends were reported by Sharma *et al.* (2020) [15] in crossbred cows receiving bypass protein. The modest increase in SNF and lactose reflects improved energy metabolism, possibly due to vitamin D₃ and E, which support glucose availability

for lactose production (Goff, 2018) [5]. These improvements are economically relevant in India, where milk pricing is strongly influenced by fat and SNF content (NDDB, 2022) [10].

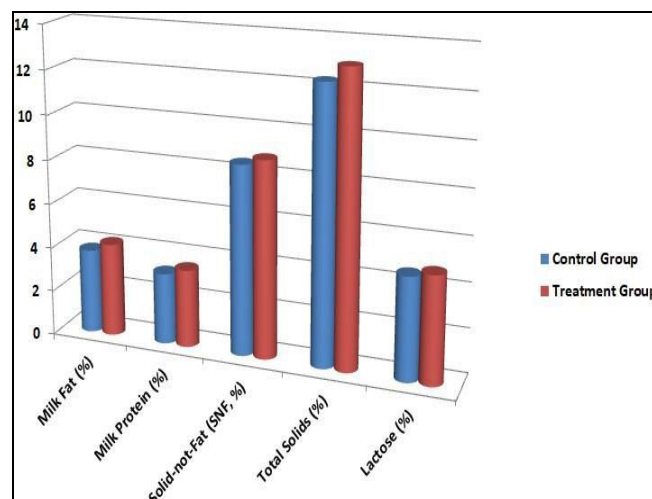


Fig 2: Comparison of Milk Composition Parameters

c. Economic Implications

Supplementation increased gross income and net profit despite slightly higher feed costs. The treatment group generated ₹615.6/cow/day gross income versus ₹520.6/cow/day in the control group, resulting in 22.7% higher net profit (₹405.6 vs. ₹330.6/cow/day).

Table 3: Economic Analysis of Nutritional Supplementation

Parameter	Control Group	Treatment Group	Difference
Feed Cost (₹/cow/day)	190	210	20
Milk Yield (L/day)	13.7	16.2	2.5
Milk Price (₹/L)	38	38	—
Gross Income (₹/cow/day)	520.6	615.6	95
Net Profit (₹/cow/day)	330.6	405.6	75
% Increase in Profit	—	—	22.7

The primary driver of increased profitability was the improvement in milk yield and fat content. These findings

agree with Lean *et al.* (2018) [7], who reported that strategic supplementation can significantly increase net returns.

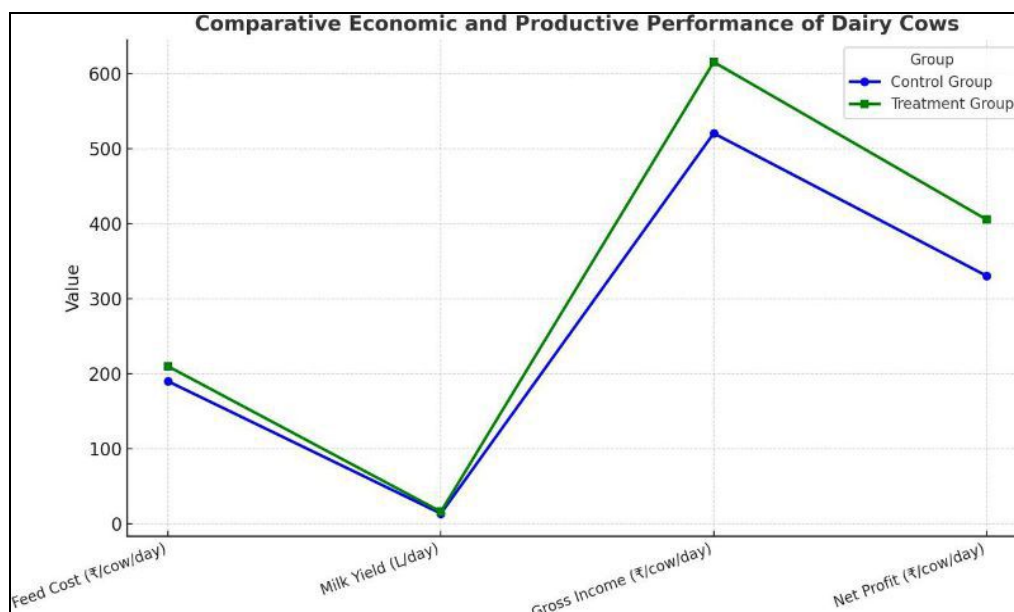


Fig 3: Comparative economic and productive performance of dairy cows

However, adoption by smallholders may be constrained by upfront costs, underscoring the need for targeted extension interventions (Moran, 2005) [9].

The 22.7% increase in net profit underscores the cost-effectiveness of supplementation, particularly in markets where milk fat commands a premium (NDDB, 2022) [10].

Summary and Conclusion

This study demonstrated that supplementation with bypass protein, chelated minerals, and vitamins A, D₃, and E significantly improves milk yield, composition, and profitability in crossbred lactating cows under tropical conditions. The treatment group exhibited an 18.2% increase in milk yield, along with notable improvements in milk fat, protein, SNF, and total solids. Economic analysis revealed a 22.7% increase in net profit, indicating that the additional feed cost was offset by enhanced production.

These findings highlight the potential of integrated nutritional strategies to enhance dairy productivity and economic viability. Wider adoption among smallholders may require cost-effective formulations and capacity-building initiatives. Future research should investigate long-term effects across different lactation stages and breeds to optimize supplementation strategies.

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