IMPACT OF FEED ON MILK PRODUCTION AND COMPOSITION IN DAIRY CATTLE

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Abstract
The objective of the study was to examine the responses of lactating dairy cows' milk yield and milk composition to different dietary treatments. Sixty cows were allocated to three groups: a standard corn–soybean–based control group (n = 20), a high-protein diet group containing canola meal and undegradable protein supplementation of the rumen (n = 22), or a high fiber-based forage/bypass fat-supplemented group (n = 18). The daily milk yield and milk composition (milk fat, protein, lactose concentration, and milk urea nitrogen-MUN) were measured and analyzed by one-way analysis of variance in SPSS. There was a significant difference in milk yield among the dietary treatments (F (2,57) = 12.31, p <0.001), and cows receiving the high-protein diet had higher milk yield (34.9 ± 3.9 kg/day) compared to both the control (30.2 ± 4.2 kg/day) and the high-fiber diets (30.6 ± 3.7 kg/day). Milk fat percentage was significantly higher in cows receiving the high-fiber diet (4.18 ± 0.17%) than in those fed the control (3.66 ± 0.18%) or high-protein diets (3.60 ± 0.19%) (F (2,57) = 48.6, p < 0.001). Milk protein percentage was greatest in the high-protein group (3.53 ± 0.16%), followed by the control (3.20 ± 0.13%) and high-fiber diets (3.05 ± 0.11%) (F (2,57) = 32.4, p < 0.001). Milk lactose percentage did not differ significantly

among treatments ($p > 0.05$). In contrast, MUN levels were significantly elevated in cows fed the high-protein diet (16.2 ± 1.5 mg/dL) compared with the control (11.1 ± 1.2 mg/dL) and high-fiber diets (8.9 ± 1.0 mg/dL) ($F(2,57) = 89.7$, $p < 0.001$). These findings indicate that dietary protein and fiber composition markedly influence milk yield, milk components, and nitrogen utilization efficiency in dairy cattle.

INTRODUCTION

Feeding is central to determining productivity, health, and efficiency in dairy production systems, as feed composition affects rumen function, nutrient delivery, and milk synthesis. Ruminant digestion is a specialized ability to use fibrous feeds by microbial fermentation and form volatile fatty acids (VFA) as the main energy source required for milk production [1]. Proper formulation of dairy rations is thus essential to provide appropriate levels of energy, protein, and fiber in the diet to sustain physiological needs for lactation without compromising rumen stability. Feeding standards, such as the Council, Nutrition [2], stress that both the amount and type of nutrients provided in feed are important for maximizing milk yield and composition. Moreover, nutrient partitioning during lactation is intended to favor milk synthesis rather than other body functions, which may emphasize the sensitivity of milk composition to dietary changes [3].

Diet and energetics are critical for milk yield, especially during periods of high metabolism. Dietary composition influences voluntary DMI via physical, metabolic, and endocrine processes that alter the availability of nutrients used for milk production [4]. The quality of the forage (Feeding stuff) as well as its digestibility and consequently dietary energy density influence animal performance and lactation yield directly [5]. Cows undergo a substantial metabolic load during early and peak lactation, so diet must be managed carefully to ensure production is maintained and negative energy balance avoided [6]. Therefore, it is very important to know how varied feeds lead to milk yield if the productivity and metabolic health of dairy cows are to be optimized.

Besides milk volume, dietary composition has a significant impact on milk quality traits, such as fat and protein content, as well as nitrogen utilization indicators. Supply of dietary protein, specifically the rumen-degradable: rumen-undegradable protein ratio, is a key factor determining milk protein synthesis and, subsequently, production efficiency [7, 8]. Too high or too low daily protein supply can modify milk composition and nitrogen excretion, with milk urea N being one of the most used practical indicators of protein utilization efficiency [9, 10]. Also, the composition of dietary fiber is essential for rumen health and milk fat synthesis, as physically adequate fiber enhances chewing and acetate production, both of which are necessary for milk fat synthesis [11]. As sustainability and precision feeding gain increasing focus, optimizing feed formulation has become more critical than ever for improving milk yield and quality without unnecessary nutrient excretion into the environment [12, 13]. Although extensive research has been conducted on these topics, further comparison of various feed ration combinations would be essential to optimize a feeding strategy that simultaneously enhances productivity and nutrient efficiency in modern dairy systems.

2. METHODOLOGY

2.1 STUDY DESIGN

An experiment was designed as a control study to investigate the effects of several dietary regimens on milk yield and composition in dairy cows. Animals were randomized to diet treatments, and production and compositional responses of milk were observed.

2.2 STUDY ANIMALS AND MANAGEMENT

Lactating dairy cows at different parities were sampled. All the animals were clinically normal and were raised in similar housing and husbandry conditions. Cows were milked twice daily according to the routine milking schedule. Management routines (housing, milking regimen, and health supervision) for the treatment groups were the same to minimize non-dietary variation.

2.3 DIETARY TREATMENTS

Cows were assigned to one of the 3 diets: a control diet formulated with a typical corn–soybean meal ration, a high-protein diet containing canola meal and rumen-undegradable protein sources, and a high-fiber diet supplemented with forage and bypass fat. Diets were balanced to meet all nutrient requirements of lactating dairy cows. Feed was given ad libitum, and the individual's intake was recorded during the dry period.

2.4 DATA COLLECTION

Parity and days in milk at sampling were recorded for each cow. Daily DMI and milk yield were calculated per cow. Milk was sampled during routine milking and subsequently analyzed for milk fat %, milk protein %, lactose %, MUN concentration, and somatic cell count by standard laboratory methods.

2.5 OUTCOME MEASURES

The dependent variable was daily milk yield (kg/day). Secondary response variables were milk fat percentage, milk protein percentage, milk lactose percentage, concentration of urea nitrogen in milk, and somatic cell count. These parameters were applied to evaluate not only production performance but also milk quality in relation to dietary treatments.

2.6 STATISTICAL ANALYSIS

Data was processed with IBM SPSS Statistics. Means and standard deviations were calculated for all variables analyzed. The normality of continuous variables was checked with the Shapiro–Wilk test and homogeneity of variance by Levene's test. The mean differences among dietary treatment groups were compared using a one-way analysis of variance (ANOVA). In the case of a strong overall effect, we compared groups using Tukey's honest significant difference post hoc test. Statistical significance was defined as $p < 0.05$ in all analyses.

3. RESULTS

3.1 DESCRIPTIVE STATISTICS

Sixty lactating dairy cows were included in the study and grouped into 3 dietary treatments: Control (corn–soybean diet), High-Protein (canola meal containing rumen undegradable protein), and High-Fiber (forage with bypass fat). Table 1 reports the Descriptive statistics of milk yield and milk composition parameters as affected by dietary treatments

Table 1: Descriptive Statistics of Milk Production and Composition Parameters By Dietary Treatment (Mean ± SD)

Variable	Control (n = 20)	High-Protein (n = 22)	High-Fiber (n = 18)
Milk yield (kg/day)	30.2 ± 4.2	34.9 ± 3.9	30.6 ± 3.7
Milk fat (%)	3.66 ± 0.18	3.60 ± 0.19	4.18 ± 0.17
Milk protein (%)	3.20 ± 0.13	3.53 ± 0.16	3.05 ± 0.11
Milk lactose (%)	4.73 ± 0.08	4.77 ± 0.09	4.72 ± 0.10
Milk urea nitrogen (mg/dL)	11.1 ± 1.2	16.2 ± 1.5	8.9 ± 1.0

3.2 EFFECT OF DIET ON MILK YIELD

One-way ANOVA indicated a significant response of dietary treatment effect on milk yield ($F(2,57) = 12.31$, $p < 0.001$). Significant differences were observed between cows fed a high-protein diet and the control and high-fiber groups; however, there was no significant difference between the control and high-fiber groups. Pairwise comparisons using Tukey's post hoc test are shown in Table 2.

Table 2: Post Hoc Comparison of Milk Yield Between Dietary Treatments (Tukey HSD)

Comparison	Mean difference (kg/day)	p-value
High-Protein vs Control	+4.7	<0.001
High-Protein vs High-Fiber	+4.3	<0.001
Control vs High-Fiber	−0.4	0.78

3.3 EFFECT OF DIET ON MILK FAT PERCENTAGE

Dietary treatment had a significant effect on milk fat percentage ($F(2,57) = 48.6$, $p < 0.001$). According to Table 1, cows fed a high-fiber diet had a higher milk fat percentage than those in both the control and high-protein groups. Statistical analysis using post hoc tests revealed that the high-fiber diet differed significantly from the other 2 diets ($p < 0.001$).

3.4 EFFECT OF DIET ON MILK PROTEIN PERCENTAGE

A highly significant dietary treatment effect was also observed for milk protein percentage ($F (2,57) = 32.4$, $p < 0.001$). The percentage of milk protein was most significant in cows feed a high-protein diet, intermediate in the control, and lowest in the high-fiber diets (Table 1). Tukey's post hoc test showed that the high-protein diet differed significantly from both the control and the fiber-high diets ($p < 0.001$).

3.5 EFFECT OF DIET ON MILK LACTOSE AND MILK UREA NITROGEN

There was no significant difference ($p > 0.05$) for milk lactose percentage between dietary treatments and mean values were approximately the same among all groups (Table 1). Milk urea nitrogen concentration, on the other hand, was strongly influenced by diet ($F (2,57) = 89.7$ $p < 0.001$). The concentration of milk - urea nitrogen was far higher in the high-protein diet than both high-fiber and control diets, whereas the lowest value was in the high-fiber group (Table 1).

4. DISCUSSION

Diet composition had a significant effect on milk yield, as indicated by the results: cows fed a high-protein diet produced more milk than those fed a control or a high-fiber diet. This finding is not surprising considering the large body of evidence that demonstrates a positive effect of elevated rumen degradable crude protein and rumen-undegradable protein availability for mammary synthesis and thus milk output [7, 14]. These responses are also observed when energy and protein supply are matched [15], resulting in greater nitrogen utilization efficiency and milk yield. The above-described greater milk yield in cows fed a high-protein diet aligns well with existing nutritional knowledge and earlier experimental data.

The concentration of milk fat was influenced by the diet, with a higher proportion in cows fed high-fiber diets, indicating that the physical effectiveness of fiber and rumen fermentation patterns determines milk fat synthesis. Forage-based diets stimulate acetate and butyrate production in the rumen, which are major precursors for de novo milk fat synthesis in the mammary gland [4, 16]. Most studies have reported that increasing fiber level and improving forage quality may prevent the depression of milk fat and enhance milk fat concentration [17]. Furthermore, supplementation of rumen-protected fat in high-fiber diets could be a means to further increase the energy density without having adverse effects on ruminal function and consequently promote milk fat output [18, 19].

Milk protein content was highest in cows fed the high-protein diet, a result consistent with previous research showing that dietary protein provision is one of the primary regulators of milk protein synthesis [20]. Sufficient pools of absorbable amino acids, especially when dietary protein and energy are concordant, also improve mammary uptake and utilization of amino acids for milk protein synthesis [14]. Genetic differences in milk protein concentration across the dietary treatments are also in agreement with previous estimates of the National Research Council based on balancing rumen-degradable and –undegradable protein to maximize milk protein yield

Milk urea nitrogen concentrations were higher for cows fed the high-protein diet, indicating more absorbed nitrogen and excessive ruminal ammonia production compared with microbial and mammary utilization. High MUN levels are accepted indicators of overfeeding protein or proteinosis of nitrogen [21, 22]. Kaufman [23] and Hristov and Jouany [24] emphasize the balance between maximizing milk production to utilize proteins for synthesis and improving nitrogen use efficiency. The results of these studies emphasize the need for precision feeding programs that maximize milk production and minimize nitrogen losses to improve economic and environmental sustainability.

5. CONCLUSION

The results of this study indicate that dietary composition is a key determinant of both milk yield and milk quality in lactating dairy cows. A high-protein diet significantly increased milk yield and milk protein concentration, underscoring the need for a balanced protein supply for optimal mammary gland function and overall productive performance. The higher milk fat percentage in the high-fiber diet, however, highlights the roles of physically adequate fiber and the rumen fermentation profile in supporting milk fat synthesis. Differences in milk urea nitrogen (%) among dietary treatments also indicated differences in nitrogen use efficiency, as cows receiving high-protein diets had higher values, suggesting a potential oversupply of protein and decreased nitrogen utilization efficiency. Taken together, these findings emphasize the need to balance dietary protein and fiber sources to achieve optimal performance while maintaining milk quality and metabolic health. Optimizing protein degradability, energy density, and neutral detergent fiber can effectively improve milk yield and composition without adverse effects on animal health or nutrient utilization. These findings add to the growing body of evidence supporting precision feeding strategies in dairy production systems and offer practical implications for nutritionists and producers to achieve more efficient, sustainable productivity. Further research should focus on longer-term feeding strategies, interactions among diet components, and their implications for environmental nitrogen losses and animal welfare across varied management systems.

6. FUNDING

Not applicable.

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