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Performance of Dairy Cattle (*Bos taurus*) Fed with Mineral-Enhanced Concentrate Diet

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RESEARCH ARTICLE INFORMATION	ABSTRACT

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This study investigated the impact of mineral-enhanced diets on the performance of Holstein-Friesian dairy cattle, specifically focusing on milk yield, feed intake, and feed conversion ratio (FCR). Twelve cows in early lactation were assigned to four dietary treatments. Over a 30-day feeding trial, performance indicators including feed intake, milk yield, feed conversion ratio (FCR), and economic returns were assessed. Results showed that Treatment 3 (T_3) significantly outperformed the other treatments across most parameters. Cows fed with T_3 had the highest cumulative feed intake (2,090 kg), milk yield (706 L), and the most efficient FCR (2.95). Economic analysis revealed that T_3 also achieved the highest net income of ₱14,790.60, return on investment of 38.09%, and feed cost efficiency of ₱21.30 per liter of milk. These findings indicate that supplementing dairy rations with 0.35% minerals enhances both biological productivity and economic viability and may be recommended as an optimal feeding strategy for improving dairy production under tropical farm conditions.

Keywords: *Dairy cow nutrition, milk yield, Feed Conversion Ratio (FCR), mineral supplementation, forage and concentrate analysis*

Introduction

The global dairy industry is a critical sector in ensuring the consistent supply of milk and dairy products to meet the nutritional needs of billions of people. Despite its importance, the industry faces challenges related to insufficient milk production, particularly in developing countries like the Philippines. The Philippine Dairy Industry Roadmap 2020-2025 identified the slow growth of dairy animal populations as a significant concern. Slow growth is due to feed-related issues and inadequate nutritional management, contributing to poor reproduction rates and low milk productivity.

Proper dairy nutrition is fundamental to improving the productivity and health of dairy cattle. Inadequate nutrition impedes not only the overall well-being of dairy animals but also the efficiency of milk production. One approach to address these challenges is the continuous supplementation of essential minerals. Azomite™, a natural volcanic mineral source that contains 70 macro, micro, and trace minerals, including rare earth elements (REEs) minerals, which are known as essential for promoting optimal growth, metabolism, immune function, and disease resistance in dairy cattle. Several university studies have reported significant improvements when Azomite® was added directly to the feed at 0.3% to 1% of the total feed mix. (AZOMITE Mineral Products, n.d.)

The issue of mineral supplementation in dairy nutrition remains an under-explored area in the Philippines, where animal health and productivity are critical for enhancing dairy farm sustainability. Mineral supplements play a crucial role in dairy farming, affecting growth, production, and reproduction in cattle. Deficiencies can lead to structural, physiological, and immunological disorders (Kumar, 2015; Velladurai et al., 2016). Essential minerals include calcium for bone development, iron for immune function, copper for male reproductive performance, selenium for immunity and antioxidant status, zinc for semen quality, manganese for enzyme function, and iodine for thyroid activity (Dey et al., 2018). Mineral requirements vary based on factors such as age, pregnancy stage, and lactation phase, with reproduction and immunity needs generally higher than maintenance requirements (Velladurai et al., 2016). Trace minerals like zinc, copper, manganese, and selenium are vital components of enzymes and proteins supporting metabolism, growth, production, and reproduction (Hossein et al., 2014). Proper mineral supplementation requires knowledge of bioavailability, sources, animal requirements, and nutrient interactions to formulate economically efficient and environmentally responsible diets (Hossein et al., 2014; Kumar, 2015).

This study aimed to evaluate the impact of a mineral-enhanced concentrate diet on the productive performance of Holstein-Friesian dairy cattle under Philippine conditions. The investigation encompassed the quantification of milk yield, feed intake, and feed conversion ratio (FCR) to determine physiological responses to dietary intervention. Proximate composition analyses were conducted on forage, conventional concentrate, and mineral-enhanced concentrate diets to compare their nutritional profiles. Furthermore, the study included an economic assessment to determine the cost-efficiency of the mineral-enhanced formulation in commercial dairy operations.

Methods

Selection of Experimental Animals

A total of 12 American Holstein-Friesian dairy cows, aged three years and in their early-lactation stage, were randomly selected for this study. The cows were in good health and dewormed prior to the experiment to ensure the validity and reliability of the results. This selection was based on the cows' age, lactation stage, and overall health, all of which are important factors in ensuring consistent performance throughout the study from March 07, 2024, to April 05, 2024.

Composition of Concentrates

The cows were fed *ad libitum* with Napier grass for 60-70 days. The concentrate diets provided to the cows were formulated with various ingredients, including rice bran D1, copra meal, corn, US Soybean Meal HP, molasses, limestone fine, salt, urea, diamond V XP, toxin binder, mineral premix (for conventional diet), Azomite™ (for diets 2-4), Capsoquin N, MDCP, Selenium, and Picutrin (vitamins).

Treatments

The experimental animals were assigned to four treatment groups, each receiving different dietary regimens. The treatments were as follows:

- T1 (Conventional Diet): Farm's standard practice with conventional mineral diet;
- T2 (0.25% Mineral Supplementation): Ad libitum Napier grass + 5 kg formulated concentrate with 0.25% minerals;
- T3 (0.35% Mineral Supplementation): Ad libitum Napier grass + 5 kg formulated concentrate with 0.35% minerals; and
- T4 (0.45% Mineral Supplementation): Ad libitum Napier grass + 5 kg formulated concentrate with 0.45% minerals.

Each treatment had three experimental animals. The treatments were assigned randomly using a Complete Randomized Design (CRD).

Feeding Regimen

The feeding trial supplementation lasted for 30 days. Holstein-Friesian cows were provided with *ad libitum* Napier grass and a 5-kg concentrate diet per day. The daily concentrate diet was divided into two equal portions: 2.5 kg in the morning and 2.5 kg in the afternoon. The feeding practice followed standard procedures for dairy cattle management to ensure consistent intake across all groups.

Data Collection

The following data points were collected throughout the study:

1. *Feed Intake (kg).* Individual feed intake was monitored daily. The total amount of feed offered (Napier grass and concentrate) and the refusals were weighed using a weighing scale. The difference was calculated to determine the actual dry matter intake per animal per day. Feed was offered ad libitum to ensure unrestricted intake of Napier grass, while concentrate feeding was rationed according to the experimental treatment levels.
2. *Milk Yield (L).* Milk production was recorded twice daily for each cow—at 9:00 a.m. and 3:00 p.m. using a milking machine. Daily milk yield was computed by summing the morning and afternoon measurements.
3. *Feed Conversion Ratio (FCR).* The feed conversion ratio was calculated using the formula: FCR=Total Feed Intake (kg)/Total Milk Yield (L)

Data Analysis

The collected data were analyzed using Analysis of Variance (ANOVA) with a single-factor design, following a Complete Randomized Design (CRD). Statistical significance was set at $p<0.05$ using Microsoft Excel's Data Analysis Toolpak. This analysis allowed for the comparison of milk yield, feed intake, and feed conversion ratio.

Ethical Considerations

This study adhered to ethical standards for animal welfare, ensuring humane treatment of the dairy cows. All experimental procedures were designed to minimize discomfort and stress, according to local and international guidelines for livestock research. There were no conflicts of interest, and the study was conducted impartially with full respect for the intellectual property involved. While the study did not involve human participants, the rights and well-being of the animal subjects were prioritized throughout the research process.

Results and Discussion

Feed Intake (kg)

The weekly and cumulative feed intake of dairy cattle subjected to different dietary treatments is presented in Table 1. During Week 1, a statistically significant difference (p=4.37x10-7) was observed among treatments. T_3 (0.35% mineral supplementation) recorded the highest feed intake at 161 kg, significantly higher than T_1 (156 kg), T_2 (158 kg), and T_4 (157 kg). This suggests an early positive response to moderate mineral inclusion, possibly due to improved palatability or metabolic stimulation. In Week 2, there were no significant differences (p=0.8853043) in feed intake across treatments. All groups showed comparable values ranging from 157 to 159 kg, indicating a temporary stabilization in consumption regardless of mineral levels. By Week 3, statistical differences re-emerged (p=0.0310668). T_3 again led with 164 kg, outperforming T_1 (160 kg), T_2 (161 kg), and T_4 (160 kg). The consistently superior intake of T_3 reinforces the benefit of moderate mineral supplementation over time. In Week 4, significant differences were also found (p=0.0118537). T_3 obtained the highest feed intake at 211 kg, significantly greater than T_1 (204 kg) and T_4 (207 kg). T_2 (207 kg) showed intermediate intake, not significantly different from either group "a" or "b", suggesting a dose-related trend.

Over the 30-day cumulative period, T_3 had the highest total feed intake at 2090 kg, significantly exceeding T_1 (2030 kg), T_2 (2050 kg), and T_4 (2040 kg). These findings indicate that 0.35% mineral supplementation (T_3) consistently promoted increased feed consumption across most weeks and overall. This trend aligns with the findings of Daniel et al. (2020) and Roshanzamir et al. (2019), who reported that appropriate trace mineral supplementation can enhance dairy cattle's appetite, nutrient absorption, and feed efficiency.

Table 1. Weekly and Cumulative Feed Intake of Dairy Cattle with Different Mineral-Enhanced Diet (kg)

TREATMENTS	Weekly and Cummulative Feel Intake (kg)				
	1st	2nd	3rd	4th	Cumulative
T1 - Conventional Diet (Farm's practice)	156 ^{d}	158	160 ^{d}	204 ^{d}	2030 ^{b}
T2 - Ad libitum Napier + 5 kg Formulated Ration with 0.25% Minerals	158 ^{b}	158	161 ^{c}	207 ^{c}	2050 ^{b}

T3 - Ad libitum Napier + 5 kg Formulated Ration with 0.35% Minerals	161 [a]	159	164 [a]	211 [a]	2090 [a]
T4 - Ad libitum Napier + 5 kg Formulated Ration with 0.45% Minerals	157 [c]	157	160 [c]	207 [b]	2040 [b]
ANOVA	*	ns	*	*	*
LSD	0.3	0.45	0.43	0.37	41.19
CV (%)	2.45	3.2	3.17	3.23	70.05

Means with the same letter are not significantly different
ns-not significant **significant at 0.05% level*

The findings from this study are consistent with previous research that explored the effects of mineral supplementation on dairy cow feed intake. Studies have shown mixed results regarding the impact of mineral supplementation on feed intake and productivity. For instance, an experiment by Friggens et al. (1998) examined the effect of feed quality on the relationship between intake and stage of lactation in dairy cows. Two total mixed diets composed of grass silage and concentrate were formulated. They found that feed intake can be influenced by the stage of lactation and diet quality, with high-concentrate diets typically leading to a decline in dry matter intake as lactation progresses. This aligns with the trend observed in the current study, where increased mineral content did not significantly impact feed intake in the first three weeks, but did show an improvement in the final week.

Similarly, Oldenbroek (1988) studied the performance in the first lactation of Holstein Friesians, Dutch Friesians, and Dutch Red and Whites that were fed two complete diets differing in roughage content. Specifically, groups of 20 Holstein Friesian (HF), 23 Dutch Red and White (DRW), and 20 Dutch Friesian (DF) heifers were fed with a complete diet with only roughage (a mixture of grass and corn-silage) or the same mixture of roughage with 50% concentrates on a dry matter basis, from 2 months before the first calving until 10 months after calving. It was reported that concentrate-based diets tend to result in higher feed intake and milk yield compared to roughage-based diets. In this study, while the experimental diets contained both roughage (Napier) and concentrate-based rations, it was the mineral content (particularly 0.35%) that appeared to enhance feed intake. This suggests that the type and concentration of minerals may be a key factor in influencing feed palatability and, consequently, intake.

Moreover, research by Vance et al. (2012) examined the performance of Holstein-Friesian (HF) and Jersey × Holstein-Friesian (J × HF) cows within a high concentrate input total confinement system (CON) and a medium concentrate input grazing system (GRZ). Eighty spring-calving dairy cows were used in a 2 (cow genotype) × 2 (milk production system) factorial design experiment. The experiment commenced when cows calved and encompassed a full lactation. With GRZ, cows were offered diets containing grass silage and concentrates [70:30 dry matter (DM) ratio] until turnout, grazed grass plus 1.0 kg of concentrate/day during a 199-d grazing period, and grass silage and concentrates (75:25 DM ratio) following rehousing and until drying-off. The experiment showed that Jersey × Holstein-Friesian crossbreds produced milk with higher fat and protein content, despite having similar solids-corrected milk yields compared to Holstein-Friesians. While this study did not focus on milk yield, it highlights the complex relationship between feed intake, diet composition, and animal productivity.

The results of this study also resonate with the findings of Harder et al. (2019), who emphasized that a good health status of high-performing dairy cows is essential for successful production. Feed intake affects the metabolic stability of dairy cows and can be used as a measurement for energy balance. By implementing feed intake and energy balance into the breeding goal, these traits provide great potential for an improvement in the health of dairy cows for breeders. In this study, fixed and random regression models were tested to establish appropriate models for further analysis of this approach. A total of 1,374 Holstein-Friesian cows and 327 Simmental cows (SI) from 12 German research farms participating in a collaboration called optiKuh were phenotyped. Feed intake data recording was standardized across farms, and energy balance was calculated using phenotypic information on milk yield, milk ingredients, live weight, gestation stage, and feed intake.

Milk Yield (L)

Table 2 presents the weekly and cumulative milk yield of dairy cattle subjected to different dietary treatments. In Week 1, a statistically significant difference ($p=4.34x10^{-7}$) in milk yield was observed. T_3 (0.35% mineral supplementation) recorded the highest production at 52.8 L, significantly outperforming T_1 (42.8 L), T_2 (47.3 L), and T_4 (44.7 L). This early advantage suggests that mineral-enhanced concentrate diets immediately contributed to increased lactation performance. In Week 2, milk yield did not differ significantly (p=0.8853043) across treatments, with values ranging from 45.0 L to 48.3 L. This temporary uniformity might be attributed to mid-lactation metabolic adjustment or environmental consistency during that period.

Statistical differences reappeared in Week 3 (p=0.0310668). T_3 again recorded the highest yield at 58.2 L, significantly surpassing T_1 (49.8 L), T_2 (52.3 L), and T_4 (50.8 L). This shows a sustained production advantage under moderate mineral supplementation. In Week 4, significant differences persisted (p=0.0118537). T_3 maintained the lead with 76.2 L, while T_1 (61.2 L) remained the lowest. T_2 and T_4 (both 67.3 L) showed statistically intermediate performance. These results indicate that both the quantity and consistency of mineral supplementation positively influenced milk yield during peak lactation.

The cumulative 30-day milk yield further validated this trend. T_3 achieved the highest yield at 706 L, significantly surpassing T_2 (641 L), T_4 (624 L), and especially T_1 (600 L). This establishes 0.35% as the most effective mineral supplementation level for sustained milk production improvement. Notably, T_4 (0.45%) did not outperform T_3, and even lagged behind T_2 in some weeks. This pattern suggests a performance threshold between 0.35% and 0.45% mineral inclusion, beyond which additional supplementation may not yield proportional benefits, or could even impair performance due to possible mineral imbalances or palatability issues.

This observation contradicts the general recommendation for natural mineral additives such as Azomite, which suggests inclusion rates ranging from 0.5% to 2% of the total ration. The current findings imply that for dairy cattle under tropical conditions, lower mineral inclusion levels (around 0.35%) may be optimal, emphasizing the importance of context-specific formulation. These findings are consistent with the work of Martono et al. (2016), who demonstrated that trace mineral supplementation can enhance milk production efficiency by improving rumen function, nutrient absorption, and overall lactation performance, with reported increases up to 20.88%.

Table 2. Weekly and Cumulative Milk Yield of Dairy Cattle with Different Mineral-Enhanced Diet (L)

TREATMENTS	Weekly and Cummulative Feel Intake (kg)				
	1st	2nd	3rd	4th	Cumulative
T1 - Conventional Diet (Farm's practice)	42.8^{d}	46.2	49.8^{d}	61.2^{d}	600^{d}
T2 - Ad libitum Napier + 5 kg Formulated Ration with 0.25% Minerals	47.3^{b}	46.7	52.3^{b}	67.3^{c}	641^{b}
T3 - Ad libitum Napier + 5 kg Formulated Ration with 0.35% Minerals	52.8^{a}	48.3	58.2^{a}	76.2^{a}	706^{a}
T4 - Ad libitum Napier + 5 kg Formulated Ration with 0.45% Minerals	44.7^{c}	45	50.8c	67.3^{b}	624^{c}
ANOVA	*	ns	ns	*	*
LSD	0.61	0.9	0.87	0.74	202.74
CV (%)	16.54	21.71	19.34	19.66	115.37

Means with the same letter are not significantly different
ns-not significant **significant at 0.05% level*

These results suggest that the inclusion of 0.35% minerals positively impacted milk yield, particularly during the later stages of the trial ($p=4.00 \times 10^{-11}$). Moreover, no significant difference in terms of cumulative milk yield among the treatments. The cumulative milk yield ranges from 79 L to 91.57 L.

Previous research supports these findings, highlighting the role of mineral supplementation in enhancing milk yield and quality. A study by Sujono and Khotimah (2022) found that adding 2% mineral-plus to concentrate feed increased milk yield to 35.46 L/head/day and improved milk quality parameters in Holstein-Friesian cows. This study used a survey method where observations were made on 30 lactating cows. The data identified included feed consumption, milk production of each cow, and milk quality (specific gravity, fat content, protein content, and total solids) of milk. Minerals were added to the concentrate feed as much as 2% with the mineral composition.

Similarly, a study by Anam et al. (2022) on 48 lactating Holstein-Friesian cows with the Body Condition Score (BCS) of 3.45±0.58 and 187.08±21.53 Days In Milk (DIM) was used in this research. All animals were randomly assigned to two dietary treatments: an unsupplemented control group (CON; 24 cows) or a group that was supplemented with a 0.5% top-up of Agromix Booster® (AGB; 24 cows) in Total Mix Ratio (TMR) for a total of 46 days. The Agromix Booster® consisted of mixed mineral calcium 243.4 g/kg, iron 12.5 g/kg, magnesium 1.8 g/kg, sodium 24.3 g/kg, phosphorous 3.2 g/kg, manganese 1.2 g/kg, zinc 439.0 mg/kg, potassium 277.9 mg/kg, copper 179.4 mg/kg, sulphur 130.4 mg/kg, copper 5.4 mg/kg, selenium 131 µg/kg, and blend essential oils (synthesized from eucalyptus, orange, lavender, soybeans, walnuts, sesame seeds and olives). Feed offered and refused was recorded daily, with refusals being maintained at 5% of the fresh intake to ensure ad libitum access to feed. The study concluded that the supplementation of mixed mineral-enriched essential oils (Agromix Booster®) at 0.5% of the feed ration could improve milk yield but did not affect milk component content and feed efficiency of Holstein-Friesian dairy cows.

Additionally, Kennedy et al. (2003) conducted a split-plot design experiment over three consecutive years using a total of 48 high genetic merit (HM) cows and 48 medium merit (MM) cows. Each was given a low (LC), medium (MC), or high (HC) level of concentrate supplementation to evaluate animal production responses. They observed that concentrate supplementation improved milk production efficiency, with responses of +1.10 kg milk per kg concentrate in early lactation and +0.94 kg in mid-lactation. Their study also showed that high genetic merit cows consumed more dry matter and produced higher milk yields than medium-merit cows, emphasizing the interplay between genetics, diet, and milk production.

Moreover, Lovell and Rusoff (1963) demonstrated that highly fortified vitamin-mineral supplements in low-concentrate rations helped maintain milk production levels comparable to those fed high-concentrate diets. A study was done on 16 high-producing Holstein cows that were used in a 112-day continuous feeding trial to study the effect of feeding a highly fortified vitamin-mineral supplement with 15:85 and 60:40 hay-concentrate ratios on milk yield and composition, conversion of total digestible nutrients (TDN) to fat-corrected milk (FCM) and digestibility of the rations. The cows fed the supplemented low-concentrate ration maintained their level of FCM production significantly.

These findings highlight the potential benefits of mineral supplementation in enhancing milk yield. However, further investigation is needed to optimize mineral levels for maximum productivity while maintaining cost-effectiveness and sustainability in dairy production systems.

Feed Conversion Ratio (FCR)

The feed conversion ratio (FCR) is a critical metric for evaluating the efficiency of dairy cows in converting feed into milk. Feed Conversion Ratio (FCR), expressed in kg of feed per liter of milk, is summarized in Table 3.

In Week 1, statistically significant differences ($p=6.32 \times 10^{-6}$) were observed across treatments. Treatment T_3 (0.35% mineral supplementation) demonstrated the lowest FCR at 3.09, indicating better feed-to-milk conversion efficiency compared to T_1 (3.73), T_2 (3.43), and T_4 (3.56). This early improvement in efficiency reflects a favorable impact of balanced mineral supplementation on nutrient utilization. During Weeks 2 and 3, no significant differences ($p>0.05$) were observed among treatments. FCR values across all groups were relatively close, suggesting a period of stabilization in nutrient assimilation or uniformity in feed response across the herd. In Week 4, statistical significance was observed again ($p=0.0397753$). T_3 again recorded the lowest FCR at 2.87, significantly outperforming T_1 (3.45) and T_4 (3.18). T_2 (3.12) was intermediate, not significantly different from T_4 but less efficient than T_3. This week's data reinforces the role of optimal mineral supplementation in maximizing feed efficiency during peak milk production phases.

Looking at the cumulative FCR, T_3 had the best overall efficiency with a value of 2.95, statistically better than T_1 (3.39) and T_4 (3.28), while T_2 (3.20) showed moderate efficiency. These findings consistently point to T_3's superior ability to convert feed into milk more efficiently across the study period. These results are supported by the findings of Sujono and Khotimah (2022), who reported that dietary enhancement with trace minerals improves ruminal fermentation and nutrient metabolism, leading to improved feed conversion and milk output efficiency in dairy cattle.

Table 3. Weekly and Cumulative Feed Conversion Ratio of Dairy Cattle with Different Mineral-Enhanced Diet (kg/L)

TREATMENTS	Weekly and Cummulative Feel Intake (kg)				
	1st	2nd	3rd	4th	Cumulative
T1 - Conventional Diet (Farm's practice)	3.73[d]	3.53	3.29	3.45[cd]	3.39[d]
T2 - Ad libitum Napier + 5 kg Formulated Ration with 0.25% Minerals	3.43[bc]	3.52	3.15	3.12[bc]	3.20[dbc]
T3 - Ad libitum Napier + 5 kg Formulated Ration with 0.35% Minerals	3.09[a]	3.79	2.95	2.87[a]	2.95[a]
T4 - Ad libitum Napier + 5 kg Formulated Ration with 0.45%	3.56[db]	3.59	3.2	3.18b	3.28[db]
ANOVA	*	ns	ns	*	*
LSD	0.27	0.16	0.14	0.19	4.27
CV (%)	7.21	3.95	4.21	5.7	95.14

Means with the same letter are not significantly different
ns-not significant **significant at 0.05% level*

Feed Conversion Ratio (FCR) in Holstein-Friesian dairy cows is influenced by various factors. The paper by Sneddon et al. (2011) provides an overview of differences between Holstein-Friesian (HF), Jersey (J), and crossbred cows, for feed conversion efficiency (FCE), dry matter intake (DMI), cheese yield, and carbon emissions. It was found that Jersey cows showed higher feed conversion efficiency compared to Holstein-Friesians, converting more feed into milk production.

Furthermore, Grainger et al. (2004) stated in their study that the efficiency of conversion of feed to milk is an important determinant of farm productivity. One factor that has received little attention is the effect of breed on the efficiency of feed use. Experimental data that have compared breeds (Holstein, Friesian, Jersey, and Holstein-Friesian x Jersey crossbred cattle) for feed efficiency were reviewed. This includes data from New Zealand, the USA, and Europe. Feeds offered ranged from grazed pasture to total mixed rations. Experiments included short-term component studies that measured feed intakes and milk production for periods ranging from 2 weeks to 7 months, whole lactation studies, farm systems comparisons over 3 years, and calorimetry experiments. Differences between breeds in feed intake capacity, efficiency of milk solids production, energy metabolism, and digestive capacity were highlighted. Opportunities for utilizing breed differences in efficiency were outlined, and future research was suggested.

Genetic improvement using breeding indices can affect dry matter intake and feed efficiency, though the definition of feed efficiency used is crucial (Coleman et al., 2010). The primary objective of the study was to quantify the effect of genetic improvement using the Irish total merit index (Economic Breeding Index) on dry matter intake and feed efficiency across lactation and to quantify the variation in performance among alternative definitions of feed efficiency.

Specifically, three genotypes of Holstein-Friesian dairy cattle were identified within the Moorepark dairy research herd: 1) low Economic Breeding Index North American Holstein-Friesian representative of the Irish national average dairy cow, 2) high genetic merit North American Holstein-Friesian, and 3) high genetic merit New Zealand Holstein-Friesian. Results showed that aggressive selection using the Irish Economic Breeding Index had no effect on dry matter intake across lactation when managed on intensive pasture-based systems of milk production, although the ranking of genotypes for feed efficiency differed depending on the definition of feed efficiency used. Performance of animals grouped on alternative definitions of feed efficiency showed that conventional definitions, such as feed conversion efficiency or residual feed intake, may be inappropriate measures of efficiency for lactating dairy cows. The results also suggest that although there are differences in feed efficiency between strains of Holstein-Friesian, there is also variation within genotypes, so that improvements in feed efficiency can be realized if the appropriate definition of feed efficiency is incorporated into breeding programs.

The objective of the study by Krpalkova et al. (2021) was to identify associations between measures of feed efficiency, feed intake, feeding rate, rumination time, feeding time, and milk production using data collected from 26 dairy cows during 3 months in 2018. Their study showed that the most efficient cows with the lowest FCR (≤1.4 kg feed/1 kg milk) had the highest rumination time (597 min/day; $p<0.05$), feeding time (298 min/day; $p<0.05$), rumination/activity ratio (4.39; $p<0.05$), and rumination/feeding ratio (2.04; $p<0.05$). Less active cows (activity time 164 min/day; $p<0.05$) were the most efficient cows with the lowest FCR (≤1.4 kg feed/1 kg milk).

The behavioral differences observed in the study provide new insight into the association of feed behavior and feed efficiency with milk performance. Incorporating feeding behavior into the dry matter intake model can improve its accuracy in the future and benefit breeding programmes. However, conventional definitions of feed efficiency may not be ideal for lactating dairy cows and alternative measures like residual solids production have been proposed (Coleman et al., 2010). Understanding these factors can help optimize milk yield and improve breeding programs for enhanced feed efficiency in dairy cows. Genetic merit and concentrate supplementation also influence grass intake and milk production, with high-merit cows demonstrating higher grass dry matter intake and milk yields (Kennedy et al., 2003).

Additionally, mixed mineral-enriched essential oils supplementation has been found to increase milk yield and solids non-fat yield, although it did not affect milk component content or feed efficiency in Holstein-Friesian cows (Anam et al., 2022). These findings suggest various approaches to optimize dairy cow nutrition and productivity.

Mineral interactions can significantly impact nutrient absorption and utilization in both humans and animals. Excessive supplementation of one mineral may lead to imbalances or antagonistic effects on others. It is well recognized that the absorption, retention, and metabolism of most essential minerals can be markedly influenced by the presence of antinutrient factors in the diet (i.e., fiber and phytate).

However, interactions can also occur between essential minerals. Indeed, under some circumstances, these interactions can be profound and have significant implications for human health. Interactions between essential minerals can be broadly classified as direct or indirect. Direct interactions are generally competitive phenomena that occur during the intestinal absorption and/or during the tissue utilization of a mineral. Indirect interactions occur when one of the minerals is involved in the metabolism of the other mineral, or when a deficiency or toxicity of one of the minerals results in hormonal changes or tissue damage, which affects the metabolism of the other mineral (Couzy et al., 1993).

Economic Analysis

The economic performance of dairy cattle fed with varying levels of mineral-enhanced concentrate diets is summarized in Tables 4 and 5. Treatment T_3 (0.35% minerals) consistently outperformed the other treatments in feed intake and milk yield, which translated into superior economic returns.

Feed Intake and Milk Yield Impact

Based on Table 4, T_3 recorded the highest cumulative feed intake at 2,090 kg and obtained the highest milk yield at 706 L, demonstrating a positive relationship between feed consumption and milk productivity. In contrast, the control group T_1 consumed the least feed (2,030 kg) and produced the lowest milk yield (600 L), reflecting lower nutrient efficiency.

Although T_4 (0.45% minerals) consumed more feed than T_1, its milk yield (624 L) did not improve significantly, suggesting that excess mineral supplementation beyond 0.35% did not enhance lactation and may lead to unnecessary increases in feed cost.

Table 4. Economic Analysis

Parameters (₱)	T1	T2	T3	T4
Total Feed Intake (kg)	2,030.00	2,050.00	2,090.00	2,040.00
Total Concentrate Consumed (kg)	450	450	450	450
Total Forage Consumed (kg)	1,580.00	1,600.00	1,640.00	1,590.00
Total Cost of Concentrate (₱)	11,689.20	11,647.80	11,759.40	11,900.70
Total Cost of Forage (₱)	3,160.00	3,200.00	3,280.00	3,180.00
Labor Cost (₱)	9,000.00	9,000.00	9,000.00	9,000.00
Total Milk Yield (L)	600	641	706	624
Milk Price (₱/L)	55	55	55	55
Total Sales (₱)	33,000.00	35,255.00	38,830.00	34,320.00
Net Income (₱)	9,150.80	11,407.20	14,790.60	10,239.30
Return on Investment (ROI) (%)	27.73	32.36	38.09	29.83

Profitability and Feed Cost Efficiency (FCE)

Table 5 presents the Feed Cost Efficiency (₱/L), representing the cost of feed required to produce one liter of milk. This metric highlights the economic efficiency of each treatment. T_3 required only ₱21.30 of feed cost to produce one liter of milk—the lowest among all treatments. As a result, T_3 achieved the highest net income at ₱14,790.60 and a return on investment (ROI) of 38.09%, confirming its status as the most economically advantageous treatment.

On the other hand, T_2 demonstrated slightly higher feed cost efficiency than T_4 and T_1, with an FCE of ₱23.15 per liter and a milk yield of 641 liters. It generated a net income of ₱11,407.20 and an ROI of 32.36%, which is still economically favorable.

Treatments T_1 and T_4, with FCE values of ₱24.75 and ₱24.16 per liter, respectively, reflected less favorable economics. The higher cost required to produce each liter of milk in these treatments contributed to lower net income and ROI, with T_1 yielding ₱9,150.80 at 27.73% ROI and T_4 producing ₱10,239.30 at 29.83% ROI. These outcomes indicate that while mineral supplementation enhances productivity and profitability, its effectiveness plateaus beyond the 0.35% level, as seen in T_4.

Table 5. Economic Analysis with Feed Cost Efficiency (FCE)

Treatment	Feed Cost (₱)	Milk Yield (L)	FCE (₱/L)	Net Income (₱)	ROI (%)
T_1- Conventional Diet (Farm's practice) Control	14,849.20	600	24.75	9,150.80	27.73%
T_2- *Ad libitum* Napier + 5 kg Formulated Ration with 0.25% Minerals	14,847.80	641	23.15	11,407.20	32.36%
T_3- *Ad libitum* Napier + 5 kg Formulated Ration with 0.35% Minerals	15,039.40	706	21.3	14,790.60	38.09%
T_4- *Ad libitum* Napier + 5 kg Formulated Ration with 0.45% Minerals	15,080.70	624	24.16	10,239.30	29.83%

Conclusion and Future Works

This study aimed to evaluate the impact of a mineral-enhanced concentrate diet on the productive performance of Holstein-Friesian dairy cattle under Philippine conditions. The results indicated that the T3 (*Ad libitum* Napier grass + 5 kg of 0.35% mineral-enriched concentrate) significantly enhanced dairy cow performance in terms of milk yield, feed intake, and feed conversion ratio compared to the conventional diet. Moreover, the economic analysis demonstrated that T3 is the most profitable and efficient dietary regimen for dairy farming, suggesting its potential for improving both animal performance and farm sustainability in the Philippines. This study contributes to the growing body of knowledge on the benefits of mineral supplementation in dairy nutrition and offers practical insights for the optimization of feeding strategies in the Philippine dairy industry.

Future research may focus on exploring the long-term impact of different mineral supplementation levels on reproduction, longevity, and overall herd health. Additionally, studies may investigate the effects of various forage types and combinations of feed ingredients to refine nutritional strategies that promote both productivity and environmental sustainability in dairy farming. Furthermore, economic models could be developed to simulate the long-term financial implications of adopting mineral-enhanced diets across a range of farm operations, and phytobiotic feeds could also be researched on dairy cows for future studies that have been tried and tested on broilers, as suggested by other researchers like Torrente-Manibog and Marcos (2024).

References

[1] Anam, M. S., Widyobroto, B. P., Astuti, A., Agus, A., & Retnaningrum, S. (2022). Effect of mixed mineral-enriched essential oils supplementation on milk production and feed efficiency of lactating dairy cows. *American Journal of Animal and Veterinary Sciences*, 17(2), 165–171.

[2] Azomite Mineral Products. (2021, October 26). Frequently asked questions about AZOMITE® fertilizer. *Azomite Trace Minerals*. https://azomite.com/frequently-asked-questions-about-azomite-mineral-products/

[3] Coleman, J., Berry, D., Pierce, K., Brennan, A., & Horan, B. (2010). Dry matter intake and feed efficiency profiles of 3 genotypes of Holstein-Friesian within pasture-based systems of milk production. *Journal of Dairy Science*, 93(9), 4318–4331. https://doi.org/10.3168/jds.2009-2686

[4] Couzy, F., Keen, C. L., Gershwin, M. E., & Mareschi, J. P. (1993). Nutritional implications of the interactions between minerals. *Progress in Food & Nutrition Science*, 17(1), 65–87.

[5] Department of Agriculture – Bureau of Agricultural Research through the UPLB Foundation, Inc., in collaboration with the Philippine Council for Agriculture and Fisheries & National Dairy Authority Department of Agriculture, Diliman, Quezon City, Philippines. (2022). *Philippine dairy industry roadmap 2020–2025*. https://www.da.gov.ph/wp-content/uploads/2023/05/Philippine-Dairy-Industry-Roadmap.pdf

[6] Dey, D., Sharma, B., Khare, A., & Gupta, S. K. (2018). Importance of mineral feeding in dairy animals: A review. *Bhartiya Krishi Anusandhan Patrika*, 33(4), 279–282. https://doi.org/10.18805/BKAP134

[7] Ertl, P., Zebeli, Q., Zollitsch, W., & Knaus, W. (2014). Feeding of by-products completely replaced cereals and pulses in dairy cows and enhanced edible feed conversion ratio. *Journal of Dairy Science*, 98(2), 1225–1233.

[8] Friggens, N., Emmans, G., Kyriazakis, I., Oldham, J., & Lewis, M. (1998). Feed intake relative to stage of lactation for dairy cows consuming total mixed diets with a high or low ratio of concentrate to forage. *Journal of Dairy Science*, 81(8), 2228–2239. https://doi.org/10.3168/jds.s0022-0302(98)75802-3

[9] Grainger, C., & Goddard, M. (2004). A review of the effects of dairy breed on feed conversion efficiency – an opportunity lost? *Science Access*, 1(1), 77–80.

[10] Harder, I., Stamer, E., Junge, W., & Thaller, G. (2019). Lactation curves and model evaluation for feed intake and energy balance in dairy cows. *Journal of Dairy Science*, 102(8), 7204–7216.

[11] Hossein, A. S., & Nasroallah, M. K. (2014). Trace mineral requirements for dairy cattle. *International Journal of Advanced Biological and Biomedical Research*, 2, 427–432.

[12] Kennedy, J., Dillon, P., Delaby, L., Faverdin, P., Stakelum, G., & Rath, M. (2003). Effect of genetic merit and concentrate supplementation on grass intake and milk production with Holstein Friesian dairy cows. *Journal of Dairy Science*, 86(2), 610–621.

[13] Krpálková, L., O'Mahony, N., Carvalho, A., Campbell, S., Corkery, G., Broderick, E., Riordan, D., & Walsh, J. (2021). Association of feed efficiency, feeding rate, and behaviour with the milk performance of dairy cows. *Dairy*, 2(4), 684–694. https://doi.org/10.3390/dairy2040053

[14] Kumar, V. (2015). Effect of minerals on dairy animal reproduction: A review. *International Journal of Livestock Research*, 5(6).

[15] Lovell, R., & Rusoff, L. (1963). Effect of a highly-fortified vitamin-mineral supplement in high- and low-concentrate rations for dairy cows. *Journal of Dairy Science*, 46(10), 1089–1093.

[16] Monte, F., Jr., & Marcos, M. J. (2024). Yield enhancement through nitrogen fertilization of Pakchong Napier grass (Pennisetum purpureum × P. glaucum). *Linker (The Journal of Emerging Research in Agriculture, Fisheries and Forestry)*, 4(2), 35–49.

[17] Nw, S., López-Villalobos, N., & Baudracco, J. (2011). Efficiency, cheese yield and carbon emissions of Holstein-Friesian, Jersey and crossbred cows: An overview. In *Proceedings of the New Zealand Society of Animal Production* (Vol. 71, pp. 214–218). New Zealand Society of Animal Production.

[18] Oldenbroek, J. K. (1988). *Feed intake and energy utilization in dairy cows of different breeds* [Doctoral dissertation, Wageningen University]. Wageningen University and Research.

[19] Oldenbroek, J., & Van Eldik, P. (1980). Differences in feed intake between Holstein Friesian, Dutch Red and White and Dutch Friesian cattle. *Livestock Production Science*, 7(1), 13–23.

[20] Sujono, N., & K., K. (2022). Evaluation of the use of Mineral-Plus on production performance and milk quality of Friesian Holstein crossbreed dairy cows. *International Journal of Agriculture and Environmental Research*, 8(4), 516–525. https://doi.org/10.51193/ijaer.2022.8401

[21] Torrente-Manibog, J., & Marcos, M. J. (2024, December 31). Growth performance of broilers fed diet with pelleted phytobiotic feeds. *Linker (The Journal of Emerging Research in Agriculture, Fisheries and Forestry)*, 4(2), 79–85.

[22] Vance, E., Ferris, C., Elliott, C., McGettrick, S., & Kilpatrick, D. (2012). Food intake, milk production, and tissue changes of Holstein-Friesian and Jersey × Holstein-Friesian dairy cows within a medium-input grazing system and a high-input total confinement system. *Journal of Dairy Science*, 95(3), 1527–1544.

[23] Velladurai, C., Selvaraju, M., & Napolean, R. E. (2016). Effects of macro and micro minerals on reproduction in dairy cattle: A review. *International Journal of Scientific Research in Science and Technology*, 2(1), 68–74.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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