Research Article

Prill Fat and Zinc Wafer Supplements Enhance Milk Yield and Quality in Smallholder Dairy Cows

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Abstract | Milk demand in Indonesia continues to rise alongside population growth, yet domestic production remains low, particularly from smallholder dairy farms. Inadequate energy and mineral content in feed limits dairy cow productivity. This study evaluated the effect of supplementary wafers containing prill fat and zinc on milk production and quality in 18 lactating dairy cows (average weight: 506.33 ± 26.84 kg) at a smallholder farm in Central Java. Using a randomized block design, cows were assigned to three treatments: R0 (control), R1 (R0 supplemented with 200 g wafer), and R2 (R0 supplemented with 400 g wafer). Variables measured included feed and nutrient intake, milk yield and quality, persistence, and profitability. After the 49-day treatment period, data were analyzed to determine the effects of each level of supplementation. Results showed that supplementation significantly increased nutrient intake, especially lipids, with the highest at 3.86 ± 0.01 g/day. A 200 g wafer improved CP, EE, CF, NFE, and TDN intake, increased milk yield by 1.72 L/day compared to before treatment, leading to a milk persistence rate of 119.30%, with a slight increase in milk fat (0.14%). However, 400 g wafer supplementation reduced milk yield by 0.67 L, likely due to excess fat disrupting rumen fermentation. Supplementation with 200 g of wafer containing prill fat and zinc improved feed-to-milk conversion efficiency in dairy cows compared to the control and higher supplementation levels.

Keywords | Dairy cows, Dairy nutrition, Feed efficiency, Milk component, Milk production, Wafer supplementation

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INTRODUCTION

Milk demand in Indonesia continues to rise alongside population growth and increased nutritional awareness. However, domestic production remains insufficient, particularly from smallholder farms employing traditional practices (Christi *et al*., 2019; Indriani *et al*., 2013). Consequently, Indonesia still relies on imports to meet the population's milk demand (Pasaribu *et al*., 2015). A primary limiting factor in dairy productivity is the deficiency of energy and minerals in the feed.

One supplementation strategy is the inclusion of fats, which serve as an effective feed supplement for dairy cows raised in tropical climates due to their high energy content and low heat increment (Santos *et al*., 2008). Putri *et al*. (2024) used a feed supplement wafer containing prill fat, which is a high-energy (TDN) supplement. The administration of 200 g of this supplement, containing 120 g of prill fat, has been proven to increase dairy cow milk production. A promising approach to enhance energy efficiency without disrupting rumen fermentation is the supplementation of prill fat a rumen-inert fat rich in palmitic acid (>85%) (Singh *et al*., 2014). Prill fat bypasses ruminal degradation and is absorbed in the small intestine, thereby improving energy balance and milk production without adversely affecting feed intake or rumen microbial activity (Singh *et al*., 2014).

Zinc supplementation in dairy cows has not been widely adopted at the smallholder farms, where energy and protein requirements are traditionally prioritized for milk production. However, zinc (Zn) is an essential mineral that plays a crucial role in immune function, enzymatic reactions, and overall metabolism. Supplementation with Zn has been shown to enhance rumen fermentation efficiency, increase bacterial populations, and improve milk quality by influencing fat and protein synthesis (NRC, 2001; Costa *et al*., 2023). According to Sunaryati *et al*. (2013), Zn supplementation can increase bacterial populations in the rumen, as bacteria require high levels of Zn (100-120 mg/kg). This increase in bacterial numbers optimizes enzyme production, making rumen fermentation more efficient and increasing VFA production, ultimately enhancing nutrient availability. Zn also functions as a component of alkaline phosphatase (AFA), which is vital in providing energy in the form of ATP (Sunaryati *et al*., 2013). Consistent with the findings of Bakhshizadeh *et al*. (2019), using Zn in the diet of dairy cows was shown to improve rumen bacterial growth and increase the efficiency of energy utilization. This energy availability supports metabolic processes in livestock, potentially improving the efficiency of energy use for milk production.

Given the vital role of Zn in metabolism and fermentation efficiency, combining it with prill fat supplementation may provide a synergistic effect, improving both nutrient absorption and overall milk yield. However, research on the combined effects of prill fat and zinc supplementation remains limited, particularly in smallholder production systems. This study aimed to evaluate the impact of wafer supplements containing prill fat and zinc on feed intake, milk production, and milk quality in lactating cows raised under smallholder conditions. Wafer supplements are pratical because they increase nutrient density, extend shelf life, simplify storage and transportation, and enhance palatability (Adelina *et al*., 2020; Harahap *et al*., 2021). Wafer supplements act as effective complementary feeds, aiming to boost livestock productivity and improve overall feed quality (Salvia *et al*., 2022).

MATERIALS AND METHODS

The study was conducted over a period of six months, from June to November 2024. The supplement wafers containing prill fat and zinc were produced at the Feed Industry Laboratory, Faculty of Animal Science, IPB University. The feeding trial was carried out in Mundu Village, Tulung District, Klaten Regency, Central Java. The materials used in this study included 18 lactating dairy cows with an average body weight of 506.33 ± 26.85 kg, raised in smallholder farms in Mundu Village, Tulung District, Klaten Regency, Central Java. The main feed supplement used in this study was a wafer supplement containing prill fat and Zn.

Feeds and feeding

Feed and wafer supplements were provided twice daily (at 06:00 and 15:00 Western Indonesian Time [WIB]) for 49 days. Feed intake was recorded weekly, while milk production and quality were measured weekly and daily during the final two weeks. The experimental cows had an average body weight of 506.33 ± 26.85 kg and produced 9.09 ± 2.79 L of milk per day. The ration contained 12.24% crude protein and 69.56% TDN, which met the requirements based on NRC (2001).

The ration consisted of forage and concentrate, formulated based on the feeding practices of local smallholder farms, where feed and management routines were applied uniformly across all treatments (Table 1). The cows used in this study were sourced from smallholder farms, so the feeding and management practices were aligned with local farmer routines to ensure uniformity across treatments. A wafer supplement containing prill fat and Zn was added to improve cow performance (Table 2). The wafer was formulated with 2% vitamin-mineral premix, providing 0.412 g of Zn per 400 g of wafer. This zinc content is still within the recommended supplementation limits for lactating dairy cows according to NRC (2001). Wafer production was carried out at the Feed Industry Laboratory, Faculty of Animal Science, IPB University, following a process illustrated in Figure 1 and based on the ration composition in Table 2. The wafers were pressed at a temperature of 45°C for 4 minutes to ensure proper binding and shaping.

Table 1: Feed composition and nutrient content of dairy cow ration before the study.

Feed composition	R0	R1	R2
Forage (kg DM/day)	5.37 ± 0.05	5.22 ± 0.18	5.55 ± 0.11
Concentrate (kg DM/day)	4.65 ± 0.04	4.85 ± 0.15	4.41 ± 0.57
Total (kg DM/day)	10.02 ± 0.05	10.06 ± 0.19	9.95 ± 0.59
Nutrient composition (%)*			
Crude protein	12.04	12.06	11.77
Ether extract	2.93	2.84	2.87
Crude fiber	16.83	17.21	17.03
NFE	60.29	60.09	60.26
TDN**	69.37	68.98	69.08

Note:*Results from the Laboratory of Feed Science and Technology (2024).**TDN (%)= 70.6 + (0.259×%CP)+(1.01×%EE) – (0.76 × %CF) + (0.091×%NFE) (Sutardi, 1980). R0 = Initial control ration, R1 = Initial R1 ration, R2 = Initial R2 ration.

Table 2: Proportion and nutrient content of supplement wafer containing prill fat and zinc.

Feed ingredients	Percentage (%)
Cassava pulp (onggok)	30
Prill fat	30
Molases	6.25
Corn gluten feed (CGF)	30
Vitamins and minerals	2
CaCO3	1
Salt	0.75
Nutrient content (%)*	
Dry matter	88.49
Ash	5.82
Crude protein	9.82
Ether extract	31.99
Crude fiber	15.78
NFE (Nitrogen-Free Exctract)	36.59
TDN (Total Digestible Nutrient)**	96.8

Note: *Results from the Laboratory of Feed Science and Technology (2024).**TDN (%) = 70.6 + (0.259 × %CP) + (1.01 × %EE) – (0.76 × %CF) + (0.091 × %NFE) (Sutardi, 1980).

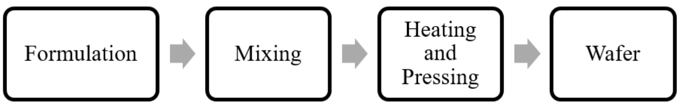

Figure 1: Stages of supplement wafer production containing prill fat and zinc.

Analytical procedures

Feed samples were analyzed for proximate composition using standard AOAC (2005) methods. Parameters included dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), ash, and nitrogen-free extract (NFE).

Milk quality was assessed using a calibrated Lactoscan Milk Analyzer. Parameters evaluated were fat, protein, lactose, solid non-fat (SNF), and density. The Lactoscan was sterilized and calibrated daily with control solutions.

Milk production persistency was calculated using the formula:

$$\text{Persistency} = 100 + \left(\frac{\textit{final milk production}(L/day) - \textit{initial milk production}(L/day)}{\textit{initial milk production}\ (L/day)}\right) \times 100\%$$

Feed-to-milk conversion efficiency (FMCE) was determined using:

$$\text{Feed} - \text{to} - \text{milk conversion efficiency} = \frac{DMI\ (kg)}{Milk\ production\ (kg)}$$

Data analysis

The treatments were: R0 (control), R1 (R0 + 200 g wafer), and R2 (R0 + 400 g wafer). A Randomized Block Design (RBD) was used with three treatments and three blocks based on initial milk production levels: low (≤8.5 L/day), medium (8.6–11.5 L/day), and high (≥11.6 L/day). The grouping was based on initial milk production to minimize baseline variation, as all cows had similar body weight (506.33 ± 26.84 kg) and were in the same lactation stage, ensuring uniformity in body condition and lactation status. Data were analyzed using Analysis of Variance (ANOVA) to assess treatment effects. Significant differences between means were denoted using different superscript letters based on Duncan's Multiple Range Test (DMRT) at a 5% significance level ($p<0.05$). Polynomial regression was used to analyze trends and optimize wafer supplementation for milk yield and persistency.

RESULT AND DISCUSSION

Effect wafer supplementation of dry matter and nutrient intake

Wafer supplementation significantly affected ($p<0.05$) the intake of crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen-free extract (NFE), and total digestible nutrients (TDN). However, it did not significantly affect ($p>0.05$) dry matter intake (DMI). The results of dry matter and nutrient intake of dairy cows at smallholder farms in Mundu Village are presented in Table 3.

Table 3: Dry matter and nutrient intake in dairy cows.

Parameter	R0	R1	R2
Forage (kg DM/day)	4.80±0.87	4.75±0.78	5.20±0.82
Concentrate (kg DM/day)	5.11±0.87	5.37±0.78	4.84±0.99
Total (kg DM/day)	9.91±0.04	10.12±0.19	10.05±0.58
Ratio (%) (F:C)	48.48:51.52	46.94:53.06	51.80:48.20
Nutrient intake (%)			
Crude protein	11.91 ± 0.00^{b}	11.94 ± 0.01^{b}	11.54 ± 0.09^{a}
Ether extract	2.92 ± 0.00^{a}	3.33 ± 0.00^{b}	3.86 ± 0.01^{c}
Crude fiber	16.99 ± 0.01^{a}	17.38 ± 0.06^{b}	17.28 ± 0.12^{ab}
NFE	60.29 ± 0.02^{c}	59.70 ± 0.11^{b}	59.49 ± 0.33^{a}
TDN*	69.17 ± 0.02^{a}	69.19 ± 0.10^{b}	69.60 ± 0.38^{c}

Note: * TDN (%) = 70.6 + (0.259 × %CP) + (1.01 × %EE) – (0.76 × %CF) + (0.091 × %NFE) (Sutardi, 1980). R0 = Control ration, R1 = R0 + 200 g wafer, R2 = R0 + 400 g wafer. Different superscripts indicate significant differences ($p<0.05$)

Lactating dairy cows in this study had an average body weight of 506.33 ± 26.85 kg and produced 9.09 ± 2.79 L of milk per day. Their DMI was relatively low, only 2% of body weight, below the NRC (2001) standard of 2.3%. This may be due to inconsistent forage quality from farmers' fields, influenced by seasonal variations. Furthermore, the sequence in which forage and concentrate were offered where forage was given first may have reduced intake due to increased rumen fill and slower digestion (Astuti *et al*., 2015; Hume, 1982).

Crude protein (CP) intake significantly differed among treatments ($p<0.05$), driven by differences in dry matter intake and dietary CP levels (Setiadi *et al*., 2020). All groups met the NRC (2001) minimum of 10.1%, but the R2 group had the lowest CP intake (11.54 ± 0.09%) likely due to prill fat interfering with rumen microbial activity (Faradilla *et al*., 2019). Excess zinc may also reduce microbial protein synthesis (Suryani *et al*., 2014) which supplies up to 90% of ruminants' amino acids (Russell *et al*., 2009).

The average EE intake increased with higher levels of wafer supplementation. The wafer used contained a high fat content of 31.99% (Table 2), which contributed to the increase in EE intake as the level of wafer supplementation increased. EE intake in all treatments remained within the normal range, with the highest value observed in the R2 ration, which included 400 g of supplemental wafer, reaching 3.86% of dry matter (DM). This aligns with NRC (2001), which states that the maximum recommended fat intake for ruminants is 5% of DM.

Crude fiber (CF) intake in treatments R1 and R2 did not differ significantly, yet both were higher than in R0. This is likely due to the relatively high CF content of the supplemental wafer, which was 15.78 % (Table 2). The relatively uniform provision of forage may have resulted in similar CF intake across treatments. The crude fiber content in dairy cow rations should not be less than 13%, as lower levels can lead to a decrease in milk fat (NRC, 2001). The results showed that the average CF intake at the smallholder farm in Mundu Village met the requirements for lactating dairy cows, with an average of 17.22 ± 0.22%. The increasing CF intake observed in this study may be attributed to the relatively high CF content in the supplemental wafer, which was 15.78%.

The NFE content tended to decrease with increasing wafer supplementation levels. Sari *et al*. (2015) stated that the NFE content in a feed ingredient is influenced by other nutritional components, such as ash, crude protein, crude fiber, and crude fat, which were also high in this treatment. Additionally, Nugraheni *et al*. (2022) reported that other nutrients, including protein, fat, and crude fiber, also affect the NFE content. This aligns with Wodzicka *et al*. (1993) stated that feed intake is influenced by temperature, palatability, physiology, feed quality, body weight, and milk production.

TDN intake increased with higher wafer supplementation due to the wafer's high TDN content (96.8%) (Table 2). Fat intake contributes to TDN, which is calculated from nutrient components such as ash, crude protein, fiber, fat, and NFE (Indah *et al*., 2020). TDN reflects the total energy available from feed (Mastopan *et al*., 2014).

Effect wafer supplementation of milk production

Wafer supplementation significantly increased milk production ($p<0.05$). The initial and final milk production of dairy cows at smallholder farms in Mundu Village is presented in Table 4.

Table 4: Effect of wafer supplementation on milk production.

Treat-ment	Milk production (L)		Difference (Δ)
	Before	After	
R0	9.06 ± 2.01	8.98 ± 1.89	-0.08[ab]
R1	8.97 ± 2.89	10.69 ± 3.69	1.72[b]
R2	9.25 ± 3.65	8.58 ± 3.34	-0.67[a]

Note: R0 = Control ration, R1 = R0 + 200 g wafer, R2 = R0 + 400 g wafer. Different superscripts indicate significant differences ($p<0.05$).

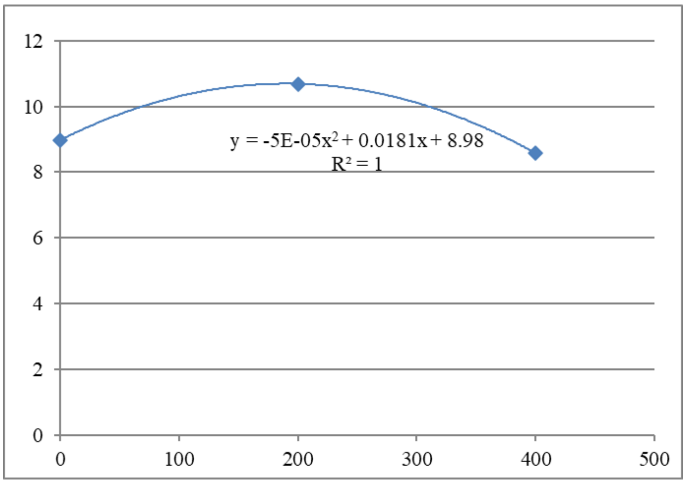

Figure 2: Effect of wafer supplement on milk production. Note: $R^2 = 1$ reflects a perfect fit to the treatment means of milk production.

The graph (Figure 2) presents a polynomial regression analysis illustrating the trend between wafer supplementation level and milk production. Based on the mean values of each treatment, a quadratic equation was derived: $y = -5E\text{-}05x^2 + 0.0181x + 8.98$, with a maximum point at approximately 181 g of wafer supplementation. This point represents the optimal supplementation level at which milk production peaks before declining at higher levels. The coefficient of determination ($R^2 = 1$) indicates a perfect fit to the data, which is expected since the analysis was based on the mean values of each treatment.

In the control group (R0), milk production decreased by

-0.08 L, indicating that the basal di*et al*one was insufficient to meet the cows' energy needs. The best result was in treatment R1, with 200 g of wafer supplement increasing milk production by 1.72 L, likely due to the prill fat content. Prill fat, a high-energy fat, bypasses the rumen and is absorbed in the small intestine, enhancing energy availability (Singh *et al*., 2014).

The Total Digestible Nutrient (TDN) intake in the R2 group was 69.19 ± 0.10%, meeting the nutritional needs of the cows. TDN provides glucose, a precursor for milk synthesis, and helps prevent negative energy balance (Astuti *et al*., 2013). Crude protein (CP) intake also played a role in increasing milk production, supporting microbial protein synthesis in the rumen, and enhancing fiber digestibility (Adi *et al*., 2020). Zinc supplementation in the wafer improved nutrient utilization and rumen microbial activity. Zinc supports the immune system and prevents deficiencies that could lead to mastitis, a major cause of reduced milk production (Blomquist, 2008; Sunaryati *et al*., 2013). Zinc is a cofactor for alkaline phosphatase, an enzyme critical for ATP-mediated energy production, thereby enhancing milk production efficiency (Sunaryati *et al*., 2013). Yang and Li (2015) also reported that zinc enhances the immune system of ruminants, reducing the risk of mastitis, which can otherwise lead to decreased milk production.

However, the addition of 400 g wafer (R2) caused a reduction of -0.67 L in milk production. The decrease in SNF and milk protein values in the R2 treatment (Table 6) may indicate disturbances in rumen fermentation or digestive efficiency. Nugroho and Ratnaduhita (2022) stated that SNF levels are inversely related to milk fat content, as SNF comprises the solid components of milk excluding fat. This reduction may have been caused by an excess of bypass fat, which disrupts rumen fermentation balance and reduces fiber digestibility. High fat levels in the rumen can coat rumen microbes, leading to microbial death and impaired digestion, ultimately disturbing the microbial balance in the rumen (Faradilla *et al*., 2019). This decline also suggests that the protected fat in the form of prill fat did not fully bypass the rumen, meaning some fat dissolved in the rumen. Such an imbalance may lead to an overall decrease in feed intake, reducing the availability of essential nutrients for milk production.

Effect wafer supplementation of milk persistence

High persistence indicates a slow decline in milk production, while low persistence reflects a rapid decline (Cole and Null, 2009). The results showed an effect ($p<0.05$) of wafer supplementation on milk production persistence. The results of milk persistence in dairy cows at smallholder farms in Mundu Village are presented in Table 5.

Table 5: Persistence of dairy cows milk production.

Treatment	Milk production persistence (%)
R0	99.9 ± 9.69[a]
R1	119.30 ± 13.01[b]
R2	95.20 ± 17.47[a]

Note: R0 = Control ration, R1 = R0 + 200 g wafer, R2 = R0 + 400 g wafer. Different superscripts indicate significant differences ($p<0.05$)

The graph (Figure 3) presents a polynomial regression analysis illustrating the trend between wafer supplementation level and milk production persistence. Based on the mean values of each treatment, a quadratic equation was derived: $y= 0.0005x^2 + 0.205x +99.9$, with a maximum point at approximately 205 g of wafer supplementation. This point represents the optimal supplementation level at which milk persistence peaks before declining at higher levels. The coefficient of determination ($R^2 = 1$) indicates a perfect fit to the data, which is expected since the analysis was based on the mean values of each treatment.

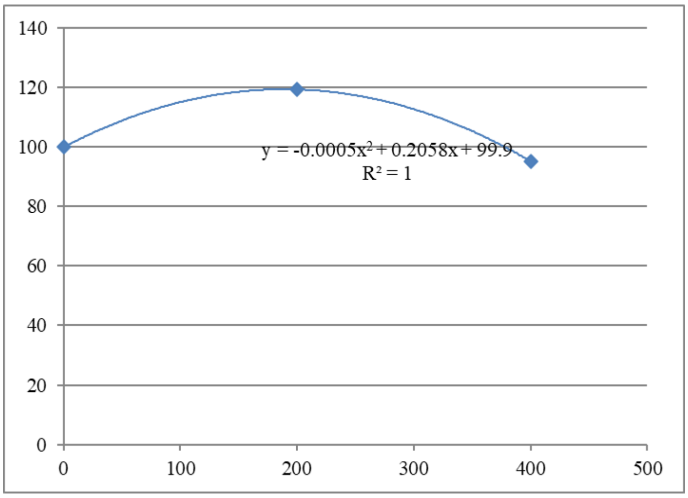

Figure 3: Persistence of dairy cow milk production after wafer supplementation feeding.
Note: $R^2 = 1$ reflects a perfect fit to the treatment means of milk persistence.

Milk production persistence in R1 (200 g wafer supplementation) was 119.30% (Table 5), consistent with Shelke (2012), who reported a 119% increase with prill fat. This was higher than the 110.6% persistence observed by Riestanti *et al.* (2021) with 2% prill fat. Zinc supplementation also supports milk production by enhancing mammary function (Oconitrillo *et al*., 2024) and activating signaling pathways in mammary cells (Kelleher *et al*., 2009). An improvement in mammary gland function may be inferred from the increased milk yield observed in the R2 treatment, where supplementation with 200 g of wafer resulted in a production increase of 1.72 L (Table 4). The 119.30% persistence suggests that prill fat and Zn supplementation maintain milk production after peak lactation. This aligns with the role of Zn in improving mammary gland function (Kelleher *et al*., 2009) and prill fat as an alternative energy source (Singh *et al*., 2014).

The persistence of milk production in the control treatment (R0) and the treatment with 400 g of wafer supplementation (R2) showed a decline, with persistence values of 99,9% and 95,20%, respectively. However, this decline remained stable, with only a slight decrease. The normal persistence rate for dairy cows ranges from 89% to 92% (Lowry, 1990). Lactation period and cow age are closely linked-milk production typically peaks in the second to fourth lactation (Siska and Anggrayni, 2020; Fadlelmoula *et al*., 2007), then gradually declines due to reduced muscle and gland function (Mahmud *et al*., 2020). In this study, cows in their first to third lactation showed no significant decline in milk yield over the 49-day trial, indicating they were still in an optimal production phase.

Effect wafer supplementation of milk components

The initial and final milk quality of dairy cows at smallholder farms in Mundu Village is presented in Table 6. Wafer supplementation containing prill fat and zinc significantly increased milk fat content. The highest increase was observed in R2 with 400 g wafer supplementation, reaching 0.14%. This increase may be attributed to prill fat, which serves as a bypass fat, absorbed directly in the small intestine, enhancing milk fat content (Singh *et al*., 2014). Fatty acids produced in the rumen play a crucial role in milk fat synthesis (Wina *et al*., 2013). Zinc supplementation also contributed to higher milk fat levels by enhancing rumen microbial activity, which supports the synthesis of volatile fatty acids (VFA) like acetate, crucial for milk fat production (Suhendra *et al*., 2015).

However, the solid non-fat (SNF) content decreased in R2 by 0.68%, likely due to the higher milk fat content. SNF is inversely proportional to milk fat, with protein and lactose content significantly influencing SNF levels (Christi and Rohayati, 2017). Milk density remained constant across all treatments, influenced by dry matter content and fat levels (Suhendra *et al*., 2020; Christi *et al*., 2022). Zinc also enhanced microbial fermentation in the rumen, indirectly affecting milk density (Rosartio *et al*., 2015).

Milk protein content decreased slightly in R1 by -0.11%, but remained within the SNI standard (2.8%). Zinc plays a role in protein metabolism and helps maintain milk protein stability (Roohani *et al*., 2013). The decline in protein content could be attributed to reduced protein intake in R1 and R2, as well as the use of prill fat for fat synthesis instead of protein (Sigit *et al*., 2021). Milk lactose content decreased by 0.17% in R1, possibly due to the influence of prill fat on glucose metabolism. Excess energy in the body is stored as glucose in the liver, where it serves as a precursor for lactose synthesis in milk (Suhendra *et al*., 2015). Lactose is a carbohydrate in milk formed by the combination of glucose and galactose (Vergi *et al*., 2016). The reduction in lactose levels may occur because glucose is more readily utilized for fat synthesis, thereby decreasing the amount of glucose available for lactose synthesis in milk.

Table 6: Effect of wafer supplementation on milk components

Milk components		Treatment		
		R0	R1	R2
Fat (%)	Before	4.51±0.59	4.22±1.41	4.13±0.50
	After	4.41±1.08	4.29±1.07	4.27±1.22
	Difference (Δ)	-0.10	0.07	0.14
Solid non fat (%)	Before	8.19±0.27	8.20±0.27	8.32±0.36
	After	8.03±0.48	7.96 ±0.36	7.64±0.93
	Difference (Δ)	-0.16	-0.25	-0.68
Density (g ml^{-1})	Before	1.026±0.002	1.026±0.002	1.027±0.002
	After	1.027±0.003	1.027±0.001	1.028±0.001
	Difference (Δ)	0.001	0.001	0.001
Protein (%)	Before	2.99±0.24	3.00±0.10	3.03±0.12
	After	2.93±0.18	2.90±0.14	2.91±0.15
	Difference (Δ)	-0.06	-0.09	-0.11
Lactose (%)	Before	4.50±0.29	4.48±0.20	4.56±0.19
	After	4.41±0.27	4.37±0.20	4.39±0.23
	Difference (Δ)	-0.09	-0.10	-0.17

Note: R0 = Control ration, R1 = R0 + 200 g wafer, R2 = R0 + 400 g wafer.

Effect wafer supplementation on farm profitability

The results showed that wafer supplementation containing prill fat and Zn improved feed-to-milk conversion efficiency. The highest improvement was observed in treatment R1 (200 g wafer supplementation), with a value of 1.06 ± 0.38 kg milk per 1 kg of dry matter intake. This indicates that 200 g of wafer supplementation enhances feed conversion efficiency into milk compared to the control ration (R0) and the 400 g wafer supplementation (R2). The feed-to-milk conversion efficiency (FMCE) of dairy cows at smallholder farms in Mundu Village is presented in Table 7.

The increase in feed efficiency in the R1 treatment may be due to the presence of prill fat, which contains fat that serves as a stable energy source in the rumen. Fat provides

Table 7: Impact of wafer supplementation on farm profitability.

Parameters	R0	R1	R2
Dry matter intake (kg/cow/day)	9.91±0.04	10.12±0.19	10.05±0.58
Milk production (L/cow/day)	8.97±1.89	10.69±3.69	8.58±3.35
Feed efficiency (kg milk/kg BK)	0.91±0.19	1.06±0.38	0.84±0.30

Note: R0 = Control ration, R1 = R0 + 200 g wafer, R2 = R0 + 400 g wafer.

2.25 times more energy than carbohydrates (Haryanto, 2012). This is in line with Shelke *et al.* (2012), who stated that prill fat supplementation can increase feed efficiency by up to 119%. However, a decrease was observed in the R2 treatment with the addition of prill fat and zinc-containing wafer at 400 g. This may be due to excess fat in the ration, which disrupts fermentation in the rumen. This disruption can lower the efficiency of feed conversion into milk production. The Zn content in the wafer also plays a role in improving milk production efficiency by supporting enzymatic functions and the health of the mammary gland (Kelleher *et al*., 2009).

CONCLUSION

Supplementation with 200 g of prill fat and zinc wafer increased milk production by 1,72 L/day and persistence to 119.30%, demonstrating optimal efficacy. The milk quality of lactating dairy cows remained unchanged after supplementation, except for the milk fat content, which increased by 0.14%. Supplementation with 200 g of wafer containing prill fat and zinc improved feed-to-milk conversion efficiency in dairy cows compared to the control and higher supplementation levels.

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NOVELTY STATEMENT

This study provides new evidence on the combined supplementation of prill fat and zinc wafer in smallholder diary systems, demonstrating improvement in milk yield, fat content, and lactation persistence under practical field conditions.

AUHOR'S CONTRIBUTION

Ameira Reiko Yashmine Orva conducted the experiment, collected and analyzed the data, and prepared the manuscript draft. Yuli Retnani supervised the study and reviewed the manuscript. Despal contributed to data analysis and critically reviewed the manuscript. All authors read and approved the final version of the manuscript.

Generative AI and AI-assisted technology statement

AI tools were used only for grammar and wording improvement. The authors fully verified all content.

Conflict of interest

The authors have declared no conflict of interest.

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