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RESEARCH ARTICLE

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# Production Performance and Milk Quality of Holstein Friesian Dairy Cow with the Utilization of Eggshell Meal Extract as a Source of Minerals

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## ABSTRACT

Milk production hinges on high-quality feed; minerals are indispensable in concentrate feed. Eggshells, a readily available by-product, contain essential minerals like calcium (Ca), phosphorous (P), and magnesium (Mg). Our study investigated eggshell meal as a mineral source for dairy cows. We assessed different mineral sources' impact on Holstein Friesian dairy cows' performance, blood Ca levels, and milk's macro mineral quality. The study employed a completely randomized design (CRD) with 3 treatments and 5 replicates, involving 15 Holstein Friesian dairy cows aged 4–5 years with an average weight of ±500kg. Treatments included commercial mineral source concentrate feed (T1), eggshell meal mineral source concentrate feed (T2), and eggshell meal extract mineral source concentrate feed (T3). Parameters included milk yield, dry matter intake (DMI), feed conversion efficiency (FCE), blood Ca levels, and milk quality. The study revealed that using eggshell meal significantly increased milk yield and FCE compared to commercial minerals. However, there were no significant differences in blood Ca levels, physical milk qualities (pH, specific gravity, and viscosity), chemical qualities (protein and fat), and Mg content. The eggshell meal extract treatment showed milk's highest Ca, P, and K content. In conclusion, our findings support using eggshell meal and extracts as a valuable source of Ca minerals in dairy cow diets, providing a sustainable alternative to traditional mineral supplements.

**Keywords:** Eggshell meal extract, Holstein Friesian, Milk minerals, Supplementation

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## INTRODUCTION

Early lactation milk production is influenced by the feed consumed because feed is a factor in the amount of milk produced (Adi et al., 2020). The relationship between milk yield and feed quality is integral, with a significant aspect being the inclusion of essential macro and micro minerals in the diet of dairy cows. According to Sujani et al. (2014), these minerals are critical, with dairy cows requiring over 100mg/day. Tangkilisan et al. (2021) enhances this understanding by illustrating that the composition of dairy cows' bodies comprises 60–80% inorganic material, with key macrominerals including calcium (Ca), phosphorus (P), and magnesium (Mg). Given the high mineral content of milk, lactating cows must receive an adequate supply of essential minerals like Ca, K, Mg, and P to sustain milk yield. Voronina et al. (2022) further elaborates on the importance of these minerals in developing bone and tooth tissue and their central roles in regulating nerve impulses and muscle contractions in the animal's body. The analysis deepens when examining the distribution and utility of Ca within the livestock's body system. A notable 99% of Ca is stored in the bones and teeth, with the remaining 1% circulating in the blood. Gaonkar and Chakraborty (2016) discusses the consequences of inadequate dietary Ca intake for milk yield, where the body

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compensates by extracting Ca from the bloodstream and, in the event of depletion, resorts to mining the bone stores for Ca. This scenario underscores the need to supplement dairy cow diets with sufficient Ca. However, the high costs associated with commercial Ca-Sources for these diets highlight the necessity for alternative, economical raw materials. Eggshells emerge as a promising solution in this context. Being a by-product from various industries, such as hatcheries, restaurants, bakeries, and noodle factories, eggshells contain valuable minerals, including Ca, P, and Mg. Fuadi and Arianingrum (2018) reports that eggshell meal and eggshell extract are rich in Ca, containing 36.53 and 40.71%, respectively, positioning eggshells as a viable natural source of Ca. The best way to use chicken eggshells as a source of calcium is by processing them into flour (Nuraeni et al., 2022). Utilization of eggshells as animal feed can be done by processing them into microparticle eggshell flour. Microparticle feed has a diameter of 10 - 1000 nm (Afriyanti et al., 2019). Eggshells are a perfect supplement for feed ingredients because they function to increase mineral density in bones. Eggshells contain calcium carbonate, which has a bioavailability of approximately ± 40%. Changes in the bioavailability of eggshell flour can occur due to several treatments of the eggshell, including dissolution using acid, boiling, and the terma process (Qolis et al., 2020). This discovery prompted further research into the use of eggshell meal as a mineral source in dairy cow diets, aiming for a more cost-effective and sustainable approach to fulfilling the dietary mineral requirements of dairy cows.

## MATERIALS & METHODS

The study was conducted on a smallholder farm in Panette Village, Enrekang District, Enrekang Regency, South Sulawesi, Indonesia. We meticulously designed this investigation employing a completely randomized design (CRD), encompassing three distinct treatments, applied across five replicates, thus involving 15 Holstein Friesian dairy cows aged between 4 to 5 years and averaging a body weight of around 500kg. The treatments were systematically distributed as follows: the first experiment with commercial minerals (T1), the second experiment with an eggshell meal (T2), and the third experiment with eggshell meal extract (T3). The dietary regimen for these dairy cows was carefully composed of 3% dry matter (DM) of their body weight, combining 80% nutrient-rich elephant grass (*Pennisetum purpureum*) and a balanced 20% mix of fine bran and tofu dreg (a standard concentrate). An additional 1% of minerals, integral to the cows' dietary needs, were infused into the concentrate. To ensure optimal hydration and overall well-being, drinking water was made available *ad libitum*.

The preparation of eggshell meal extract can be seen in Fig. 1 below:

Parameters observed included milk production, dry matter consumption, FCE; blood calcium levels by Arsenazo III method, (BBLK, 2024); milk protein levels by Kjeldah chemistry, and Mg had no significant effect (P>0.05). method (Dwiningrum et al., 2023); milk fat levels by Gerber method (Ismiarti and dan Purwitasari 2022); and milk mineral levels by atomic absorption spectrophotometry (SSA) method (Mahfudloh and Tirono 2010).

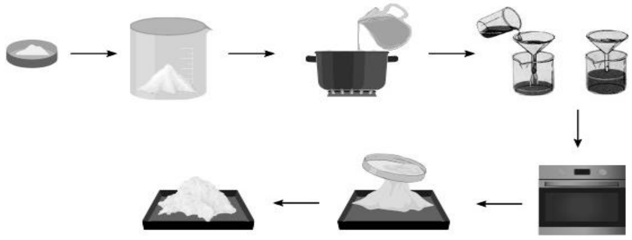

**Fig. 1:** Process of Making Eggshell Starch Extract.

### Data Analysis

The data obtained were analyzed based on ANOVA using the software SPSS for Windows ver. 27. The experiment was conducted according to a completely randomized design with three treatments and five replications and differences between treatments were tested by Duncan's test (Gaspersz, 1991).

## RESULTS

### Milk Yield Performance

Including eggshell meal and eggshell meal extract in the dairy cow diet has significantly impacted milk yield, as the statistical analysis results (ANOVA) indicated. Both eggshell meal supplementation and eggshell meal extract significantly affected milk production (Table 1) compared to commercial mineral supplementation (P<0.05). However, there were no significant differences in DMI and FCE (P>0.05), suggesting that these factors remained unaffected by the type of mineral supplementation used.

**Table 1:** Production performance of Holstein Friesian dairy cows with the utilization of eggshell meal extract as a source of minerals

| Parameters | Treatment | | | P |
|---|---|---|---|---|
| | T1 | T2 | T3 | Value |
| Milk Production (kg) | 9.73±0.11b | 12.32±0.42a | 11.25±0.31a | 0.00 |
| Dry Matter Consumption (kg) | 11.59±0.43 | 12.60±0.23 | 11.53±0.44 | 0.12 |
| FCE | 0.84±0.03 | 0.98±0.05 | 0.98±0.05 | 0.81 |

T1=Commercial mineral supplementation; T2=Eggshell meal supplementation; T3=Eggshell meal extract supplementation. FCE=Feed Conversion Efficiency (Milk Production (kg)/DM Intake kg). Values (mean±SD) bearing different letter in a row differ significantly (P<0.05).

### Blood Calcium

The results of the analysis showed that the treatment had no significant effect on blood Ca levels (P>0.05).

### Milk Quality

It is important to note that minerals are essential for dairy cows, even in small quantities. A recent study investigated the use of eggshell meal extract as a mineral source and its impact on the quality of dairy milk. The study evaluated the milk's physical quality, chemistry, and mineral content, and the results are summarized in Table 2. The study found that the physical quality of the milk, milk However, Ca, P, and K had a significant effect (P<0.05).

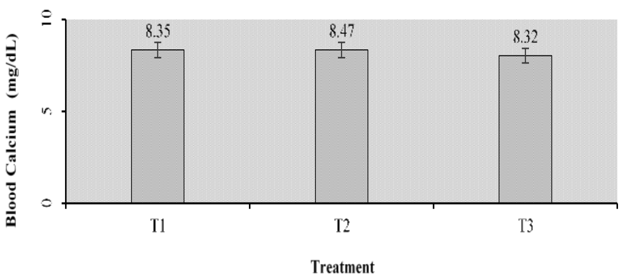


**Fig. 2:** Blood Ca levels of Holstein Friesian dairy cows using eggshell meal extract as a mineral source. T1=Commercial mineral supplementation; T2=Eggshell meal supplementation; T3=Eggshell meal extract supplementation.

## DISCUSSION

The findings indicate that the inclusion of eggshells, whether in meal form or as an extract, has a substantial impact on increasing milk production. Both eggshell meal supplementation and eggshell meal extract showed significant differences compared to commercial mineral supplementation. The heightened milk yield observed in the T1 and T2 treatments is attributed to the elevated levels of Ca present in the eggshells, regardless of whether they are extracted. The composition of eggshells, comprising 90% Ca macro minerals and less than 5% P, plays a crucial role. Eggshell minerals comprise a 2% organic matrix, Mg, P, and other elements (Hincke et al., 2012). Ca, as a nutrient mobilizer, is a significant component. Basic needs and milk yield influence the nutritional requirements of early lactation dairy cows. Basic living requirements for dairy cows are determined by body weight, health, and dairy cows' activity, while milk yield and fat contents impact the need for milk yield (Bilal et al., 2016). The milk yield range in this study was 9.73–12.32 $kg^{-1}head^{-1}day^{-1}$. In previous studies, milk yield ranged from 9.45–10.88 $kg^{-1}head^{-1}day^{-1}$. The milk yield in this study surpassed that of Suresh et al. (2023), who reported a range of 10.97–11.04 $kg^{-1}head^{-1}day^{-1}$ using a phytogenic feed additive. This affirms that using eggshells as a Ca source for dairy cows leads to increased milk yield, regardless of extraction (Liu et al., 2023). According to Talib et al. (2000), domestic dairy cows' average milk yield capacity is approximately 10 $liter^{-1}head^{-1}day^{-1}$. The quality of feed provided to lactating cows is one of the factors influencing milk yield. Concentrates given to dairy cows under improved maintenance management systems likely impact milk yield positively (Utomo and Pertiwi 2010).

Their nutritional needs influence the DMI of dairy cows. When those needs are met, the cows will cease consuming feed. Even a small percentage of nutrients, such as minerals like P at 1%, plays a significant role in the body. Ca is a vital bone development component (Tasse and Auza 2014). During early lactation, dairy cows require specific nutrient consumption, reflected in their feed's DM content. Feed DM contains essential nutrients, including fat, protein, Ca, and P (Bilal et al., 2016). Inadequate nutrient intake for milk synthesis processes will deplete the body's food reserves, leading to weight loss (Abdillah et al., 2015). When the nutritional needs of lactating cows are not met through feed intake, the milk yield of early lactation cows is compromised (Staric and Zadnik, 2010). Moreover, Ca is crucial in supporting bone development and maintaining muscle structure (Quina et al., 2017). This aligns with Te Pas et al. (2021) research, which emphasizes the significant impact of feed and nutrition on the milk yield of dairy cows. Notably, the nutritional requirements of dairy cows can differ during various stages of the lactation cycle, necessitating tailored feed formulations for specific life stages. By ensuring adequate nutrient intake, farmers can enhance the productivity and health of dairy cows, thereby benefiting milk production (Suranindyah et al., 2020).

The study highlights a unique finding where a diet supplemented with eggshell meal extract decreased blood Ca levels by 8.32mg/dL compared to other treatments, suggesting that eggshell meal extract is processed more efficiently by the body, facilitating a higher conversion rate of blood Ca to milk Ca. As Nurjanah et al. (2019) described, this phenomenon could be influenced by various factors such as protein, vitamin D, and hormonal mechanisms within the dairy cow's body. Furthermore, it addresses the complexities in maintaining blood Ca levels, especially postpartum, during the onset of milk secretion. It is observed that the body struggles to compensate for the loss of Ca in the milk, thereby reducing overall blood Ca levels. Subronto (2007) adds that an increase in milk yield necessitates a higher Ca metabolism and excretion rate. A lack of equilibrium between Ca intake and its release can

**Table 2:** Milk Quality of Holstein Friesian Dairy Cows with the utilization of Eggshell Meal Extract as a source of minerals

| Parameters | Treatment | | | P Value |
|---|---|---|---|---|
| | T1 | T2 | T3 | |
| Physical Quality of Milk | | | | |
| pH | 6.62±0.08 | 6.64±0.08 | 6.62±0.08 | 0.91 |
| Specific gravity ($g\ ML^{-3}$) | 1.03±0.00 | 1.03±0.00 | 1.02±0.00 | 0.25 |
| Viscosity (cP) | 1.42±0.06 | 1.36±0.06 | 1.48±0.08 | 0.07 |
| Milk Chemical Quality, % | | | | |
| Protein Content | 2.71±0.19 | 2.45±0.08 | 2.82±0.19 | 0.47 |
| Fat Content | 3.30±0.36 | 3.25±0.38 | 4.01±0.22 | 0.50 |
| Milk Mineral Content, % | | | | |
| Calcium (Ca) | 0.135±0.002c | 0.143±0.005b | 0.153±0.006a | 0.00 |
| Magnesium (Mg) | 0.007±0.001 | 0.009±0.002 | 0.009±0.001 | 0.42 |
| Phosphorus (P) | 0.142±0.007b | 0.163±0.009ab | 0.165±0.005a | 0.00 |
| Potassium (K) | 0.025±0.005c | 0.058±0.007b | 0.070±0.005a | 0.00 |

T1=Commercial mineral supplementation; T2=Eggshell meal supplementation; T3=Eggshell meal extract supplementation. Values (mean±SD) bearing different alphabets in a row differ significantly (P<0.05).

lead to a condition known as milk fever, underscored by a reduction in blood Ca levels. According to Wulansari et al. (2017), the absorption of Ca depends on the interaction of other minerals, the composition, and the form of calcium being consumed. This underscores the interesting complexity involved in the process of calcium absorption. Wulansari et al. (2017), the absorption of Ca is influenced by the balance of other minerals as well as the composition of the ration and chemical form of Ca. According to Parakkasi (1999), only about 30–40% of inorganic Ca is absorbed by the body. Moreover, the reduction of blood Ca levels is not solely attributed to milk yield but can also result from Ca excretion through the kidneys and bile.

The average pH value of Holstein Friesian dairy milk in each treatment adheres to the Indonesian National Standard, which ranges between 6.3 and 6.8. Factors influencing milk pH include the milking environment, sanitation of cowsheds and milking equipment, the duration of milking, and diseases causing fluctuations due to milk bacteria and drugs. Pramesthi et al. (2015) explained that variations in milk pH result from microbial and enzymatic conversion of lactose to lactic acid. The study found that Holstein Friesian dairy milk's average specific gravity value aligns with the Indonesian National Standard of 1.028–1.033. According to Christi et al. (2022), the specific gravity of milk reflects the concentration of all nutrients except water. This measurement is significantly affected by the DM in milk, consisting of carbohydrates, fats, proteins, vitamins, and minerals. Notably, the specific gravity of milk is influenced by its fat content, the primary nutritional component, as fat has a lower specific gravity than water. Therefore, a higher Specific gravity value indicates superior milk quality due to its concentrated nutrients and reduced water content, as Wulansari et al. (2017) discussed. However, the average viscosity value observed in this study does not meet the established standards, which dictate viscosity to range between 1.5 and 2.0, as per Sunardi et al. (2023). Fat, protein, lactose, and mineral content directly impact milk's viscosity (Khalifa and Ghanimah, 2013). A direct correlation exists between viscosity and specific gravity — higher viscosity means more solids in the milk, subsequently increasing its specific gravity. Viscosity and specific gravity are positively proportional. Additionally, external factors like shaking can decrease viscosity by reducing pressure, as Sunardi et al. (2023) reported.

The average protein content was 2.71-2.82, and the fat content was 3.30-4.01, following the SNI 3141.1:2011 standard of 2.8% protein and 3.0% fat. This study's feed quantity and quality meet the requirements for optimizing protein and fat levels (Fitriyanto and Triana 2013). Mutamimah et al. (2013) stated that fat content is influenced by acetic acid derived from forage, while the precursor of acetic acid comes from crude fiber fermented in the rumen so that it turns into VFA consisting of acetate, butyrate and propionate. Acetic acid then enters the secretory cells of the udder and becomes milk fat (Musnandar, 2011). Providing minerals in organic form can increase their availability so that they can be more highly absorbed in the body of livestock. Minerals in the form of organic compounds can only be partially absorbed, while insoluble minerals can pass through the digestive tract unchanged so that they cannot be used at all for livestock. The concentration of VFA in rumen fluid is influenced by feed digestibility. The higher the digestibility value, the higher the VFA produced. The concentration of VFA in the rumen is also influenced by the rate of VFA utilization by rumen microbes. The advantages of organic minerals are that they are easily absorbed by the body, easily dissolved, can directly enter the target organ cells, and can be more efficient in their use. besides that, organic minerals also help the growth of rumen bacteria to improve the speed of growth and milk production (Kusuma and Sutrisna 2014).

The protein content averaged 2.71–2.82, and the fat content ranged from 3.30–4.01, in compliance with the SNI 3141.1:2011 standard of 2.8% protein and 3.0% fat. The quantity and quality of the feed in this study meet the requirements for optimizing protein and fat levels (Fitriyanto and Triana 2013). According to Mutamimah et al. (2013), the fat content is influenced by acetic acid derived from forage, with the precursor of acetic acid coming from the rumen-fermented crude fiber, transforming into VFA-containing acetate, butyrate, and propionate. Acetic acid enters the udder's secretory cells and becomes milk fat (Musnandar, 2011). Supplying minerals in organic form can improve their availability for higher absorption in dairy cows' bodies. Organic compound minerals are only partially absorbable, while insoluble minerals pass through the digestive tract unchanged and remain unusable for dairy cows. The VFA concentration in rumen fluid is influenced by feed digestibility. Higher digestibility results in increased VFA production. The concentration of VFA in the rumen is also affected by the rate of VFA utilization by rumen microbes. Organic minerals offer advantages such as easy absorption, direct entry into target organ cells, efficient utilization, and promoting rumen bacteria growth to improve growth speed and milk production (Kusuma and Sutrisna 2014).

Eggshells, particularly those treated with CH3COOH (acetic acid), are utilized as dietary supplements for dairy cows. CH3COOH aids in breaking down the calcium carbonate (CaCO3) in eggshells into simpler, more easily absorbed forms. This process enhances the Ca availability for dairy cows and impacts other minerals such as Mg, P, and K found in high levels in extracted and unextracted eggshells. These minerals play crucial roles in various bodily metabolic and physiological functions, including bone formation, energy metabolism, protein synthesis, and cellular ionic balance. This is in line with Soeharsono (2008), Wardyaningrum (2011), Kasmiati et al. (2012), Yonata et al. (2017), Goff (2018), and Dewi Ciselia and Vivi Oktari (2021). It discusses the relationship between eggshell-derived Ca and milk quality, noting that Ca levels in milk are influenced by the cow's blood Ca and can affect the overall health of dairy cows, including risks of hypocalcemia and stunted growth due to insufficient Ca intake. The importance of Mg, P, and K from eggshells is also highlighted, underscoring their essential roles in animal health and milk yield. This noted the beneficial effects of adding minerals to dairy cows' feed, emphasizing the need for a balanced intake for optimal health and productivity.

## Conclusion

Recent findings have shown that incorporating eggshell meals into dairy cow feed leads to increased milk yield and improved feed efficiency compared to using commercial minerals. Interestingly, no significant differences were observed in blood calcium levels and the physical and chemical quality of milk between the treatment using commercial minerals and eggshell meal as a mineral source. However, the levels of essential milk minerals such as calcium, phosphorus, and potassium were found to be highest in the treatment that used eggshell meal extract. This indicates that both eggshell meal extract and unextracted eggshell meal can effectively provide calcium minerals for dairy cows.

**Conflict of Interest:** No conflict of interest.

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