American Journal of Animal and Veterinary Sciences

Original Research Paper

Eco-Friendly Eggshell Meal on Milk Yield and Quality of Holstein Friesian Cows

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Article history
Received: 25-01-2024
Revised: 19-02-2024
Accepted: 30-03-2024

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Abstract: Mineral deficiencies, particularly a lack of Calcium (Ca), can have a detrimental effect on the performance of livestock, including dairy cows. While commercial sources of Ca are commonly used in dairy cow feed, they may not always be available or affordable. In this regard, introducing a new approach that utilizes eggshell meal as a natural source of Ca can not only improve milk yield and quality but also reduce waste. Therefore, we experimented to evaluate whether an eco-friendly eggshell meal could be a viable alternative source of Ca for Holstein Friesian dairy cows and improve milk yield and quality. We used 20 cows (ethical consideration No. 470/UN4.6.4.5.31/PP36/2023) that were experimented with different levels of eggshell meal in a completely randomized design with five treatments and four replications. The experimental diets were as follows; eggshell meal 0%+ commercial mineral 100% (EM0+ CM100); EM 25%+ CM 75%; EM 50%+ CM 50%; EM 75%+ CM 25%; and EM 100%+ CM 0%. The results showed that the eco-friendly eggshell meal as a source of Ca increased the milk yield by up to 100%. The intake of dry matter and milk quality, such as pH, density, CP, and P, had a similar effect on commercial minerals. Therefore, eggshell meal could effectively replace commercial mineral supplements in the diets of Holstein Friesian dairy cows. Not only does this approach lead to increased milk yield and Ca content in the milk, but it also has the potential to reduce waste in eggshell production. By utilizing eggshell meal as a raw material for mineral source feed, dairy farmers can promote environmental sustainability and improve the efficiency of the dairy sector.

Keywords: Commercial Mineral, Eggshell Meal, Holstein Friesian Dairy Cow, Milk Quality and Yield

Introduction

Eggshell Meal (EM) is an eco-friendly Ca source and the highest source with approximately 38% calcium (Burezq, 2021). Although the proportion of mineral use is less than that of other feed raw material sources, the need for this source should be addressed in the concentrate feed. Minerals are additional feed ingredients

indispensable for livestock in increasing body weight, feed efficiency, resistance to disease and stress, and the dairy cow's reproductive system so that the dairy cow can reproduce according to their genetic potential. Mineral deficiencies can cause several problems for livestock and decrease its performance (Eltahir *et al*., 2024).

Lean and Golder (2023) stated that lactating cows require minerals, particularly macro-minerals, including Sodium Chloride (NaCl), Calcium (Ca), Phosphorus (P), and Potassium (K). These essential minerals are necessary to maximize milk production. Duplessis and Royer (2023) showed that mineral imbalance can reduce Dry Matter (DM) intake.

One of the mineral raw materials that can be utilized comes from eggshells. Eggshells have considerable potential in Indonesia. Although it is only a by-product, this eggshell contains water, proteins, lipids, and organic matter. Most of the organic matter consists of 98.5% Calcium Carbonate ($CaCO_3$) and 0.85% Magnesium Carbonate ($MgCO_3$) (Hunton, 2005; Hassan, 2015). Utilization of chicken eggshells can be used as filler material for cement or building materials (Sathiparan, 2021; Nandhini and Karthikeyan, 2022); Ca fortifier (Gómez-Alvarez and Zapata Montoya, 2024; Yang *et al*., 2022); fertilizers (Borges *et al.*, 2021) and in reducing severe joint pain (Aditya *et al*., 2021). Besides that, the EM has also been used in animal feed as a feed supplement for egg-laying hens (Sabir and Abbas, 2023). However, eggshell meal has not yet been employed for ruminants, particularly dairy cows. From an economic standpoint, the nutritional content is significant, with high levels of Ca (77%), P (0.42%), and Mg (0.52%) (Feed Biochemistry Laboratory, 2022). Thus, the opportunity to utilize it as a raw material for mineral source feed is enormous. Therefore, we aimed to determine the effect of the substitution of commercial mineral use with EM on the milk yield and quality of Holstein Friesian cows. The study introduces a novel approach to the utilization of EM eggshell meal as a natural source of Ca to boost milk yield and quality while simultaneously reducing waste in eggshell production. This technique not only promotes environmental sustainability but also offers a distinctive way to improve the efficiency of the dairy sector.

Materials and Methods

Site Description and Experimental Diet

The study was conducted at a dairy farmer in Enrekang Regency, South Sulawesi, Indonesia, from August-November 2023. The twenty Holstein Friesian cows were in the third-fifth lactation period. Feed concentrate was fed once at 7:00 a.m. post-milking while herbages, i.e., elephant grass, were fed twice daily at 08:00 a.m. and 05:00 p.m.

The concentrates as an experimental diet consisted of rice bran, coconut cake meal, fish meal, milled corn, pollard, molasses, and minerals commercial/eggshell meal. The experimental diet is presented in Table 1. The experimental diet supplemented by EM has a Crude Protein (CP) of 18% and a Total Digestible Nutrient (TDN) of 70%, which meets concentrate feed for lactating dairy cows (Azzumar *et al*., 2022)

The experimental diets were divided into five EM vs CM (%) levels, as presented in Table 2.

Measurements

Dry Matter intake (DM) was obtained from the amount of one-day consumption (24 h) and the adaptation period lasted for seven days. Milk yield was measured by the accumulation of milk yield produced in the morning and afternoon milking.

The pH was measured using a digital pH meter and density was measured using a lactodensimeter. CP concentration was analyzed using the indirect Kjeldahl method (International and Latimer Jr, 2005). Ca and P by Atomic Absorption Spectrophotometric and Colorimetric methods (International and Latimer Jr, 2005).

Data Analysis

The collected data were entered and organized in the Excel spreadsheet and then analyzed using descriptive statistics and GLM-Multivariate (SPSS, version 21.0). The experiment was carried out according to a completely randomized design with five treatments and four replications and the difference among treatments was tested by Duncan's Multiple Range Test (MRT).

Table 1: Composition and nutrition value of the experimental diet

Feedstuff	Composition (%)	DM (%)	CP (%)	TDN (%)
Rice bran	35	31.22	2.93	23.45
Coconut cake meal	15	13.29	3.20	12.15
Fish meal	15	13.46	7.35	9.22
Corn meal	15	13.02	1.62	12.12
Pollard	15	13.18	2.60	10.50
Commercial mineral/ Eggshell meal	1	1.00	0.00	0.00
Molasses	4	3.30	0.16	3.54
Total	100	88.47	17.85	70.98

Table 2: The treatment of eggshell meal as a Ca source for Holstein Friesian dairy cows

	Feedstuff of Ca source (%)	
Treatments	Eggshell Meal (EM)	Commercial Mineral (CM)
EM0+ CM100	0	100
EM25+ CM75	25	75
EM50+ CM50	50	50
EM75+ CM25	75	25
EM100+ CM0	100	0

Results and Discussion

Effect of the Eggshell Meal as a Ca Source on DM Intake and Milk Yield

The results of the study related to the DM intake of the experimental diet during the study are presented in Table 3.

The treatment level of the EM as a Ca source had no significant effect on total DM intake. The research demonstrates that the type of Ca source does not impact dairy cow appetite. However, it significantly influences their digestive metabolism.

The results of the study related to the milk yield of the experimental diet during the study are presented in Fig. 1.

At the same time, the milk yield was significantly ($p<0.05$) higher in the treatment of EM100+ CM0 than in the other treatments. The utilization of eggshell meals meets the mineral needs of dairy cows. Organic trace minerals are considerably better absorbed than inorganic forms, leading to better system absorption or tissue and blood concentrations. As a natural source of Ca, eggshells are easily digested and absorbed by the body due to their balanced mineral content. This makes the eggshell a great source of Ca for dairy cows, leading to higher milk yield. According to Liu *et al.* (2023), the eggshell protein attached to $CaCO_3$ can enhance Ca transportation in the body through the intestinal epithelial cell $CaCO_2$. In addition, Singh *et al.* (2021) discovered that eggshells contain Calcium (Ca) as well as small quantities of other microelements. Eggshell calcium is approximately 90% bioavailable and it has become the most effective natural source of calcium compared to limestone or coral sources.

The eggshell meal is a significant source of innate antioxidants (Zhu *et al*., 2022) and bioactive substances (Ahmed *et al.*, 2021). These substances enhance the synthesis of secondary metabolites in the body of dairy cows, which promote the digestive process and the assimilation of nutrients. Furthermore, eggshell meal comprises an organic matrix consisting of proteins and proteoglycans, which also contribute to the synthesis of secondary metabolites (Baláž *et al*., 2021). Incorporating EM into the diet of dairy cows can yield several health advantages and enhance their overall welfare. The findings of this study demonstrate that EM can effectively replace commercially available minerals as a calcium source in the feed for Holstein Friesian cows, increasing milk production. Consistent with the findings of Okpanachi *et al.* (2021), it has been determined that eggshell meal consists of over 90% calcium macro minerals and less than 5% phosphorus. In addition, Hasniar *et al.* (2021) stated that eggshell powder is primarily composed of mineral components (95.1%) and protein (3.3%). In addition, other factors, apart from feed, influence milk production (Dong *et al.*, 2023). Furthermore, eggshells can serve as a readily absorbable supply of calcium for the body, as calcium absorption is enhanced when derived from a natural source (Aditya *et al.*, 2021).

Influence of Eggshell Meal as a Ca Source on Milk Quality

The study results related to pH, density, CP, and mineral value of milk during the study are presented in Table 4.
The treatment level of the eco-friendly EM as a Ca source had no significant effect on the pH, density, CP, and P of dairy milk. This revealed that the type of Ca source does not affect dairy milk's pH, density, CP, and P content. However, it does significantly impact the Ca content of milk.

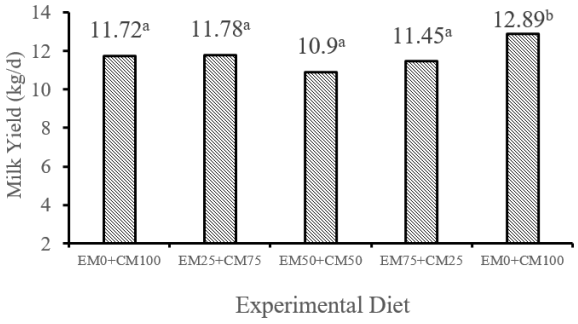

Fig. 1: Milk yield of Holstein Friesian cows fed by the eggshell meal as a Ca source

Table 3: Mean values for DM intake of Holstein Friesian dairy cows fed by the eggshell meal as a Ca source

Parameters	EM0+ CM100	EM25+ CM75	EM50+ CM50	EM75+ CM25	EM100+ CM0	SEM	P
DM intake, kg/d							
Elephant grass	7.56	7.52	6.73	6.50	6.93	0.56	0.08
Concentrate	2.64	2.61	2.64	2.64	2.64	0.32	0.88
Total DM intake	10.20	10.13	9.37	9.14	9.57	0.56	0.28

Description: Different superscripts in the same row indicate a significant difference ($p<0.05$)

Table 4: Mean values for milk quality of Holstein Friesian dairy cows fed by the eggshell meal as a Ca source

Parameters	EM0+ CM100	EM25+ CM75	EM50+ CM50	EM75+ CM25	EM100+ CM0	SEM	P
pH	6.600	6.500	6.600	6.500	6.500	0.080	0.90
Density	1.020	1.020	1.020	1.020	1.020	0.007	0.28
Crude protein (%)	2.470	2.680	2.930	2.390	2.710	0.289	0.41
Calcium (%)	0.128^{a}	0.138^{ab}	0.145^{ab}	0.139^{ab}	0.150^{b}	0.007	0.05
Phosphorus (%)	0.061	0.071	0.071	0.069	0.065	0.004	0.16

Description: Different superscripts in the same row indicate a significant difference ($p<0.05$)

In contrast, the Ca of milk had a significant ($p<0.05$) Ca tended to increase with the increase of level substitution of EM (Table 4). The highest Ca level was found in the EM100+ CM0 treatment due to the high input of the Ca level of EM. This condition tended to increase the Ca level of milk. This follows Aminah and Meikawati (2016), who stated that EM has a Ca level of 20.50%. Gul *et al*. (2024) added that the number of minerals consumed influences the high Ca content in milk.

This study revealed that EM can substitute commercial minerals as a Ca source in Holstein Friesian cow feed because it increases the Ca of the dairy cow. In this study, the value of Ca of milk is in a range with the research conducted by Stocco *et al*. (2019). The EM can be used as a source of Ca and easily absorbed by the body because the absorbance of Ca is higher when it is from a natural source (Singh *et al*., 2021; Aditya *et al*., 2021). Thus, eco-friendly eggshell meals can be substituted for commercial minerals.

Conclusion

The results showed that the eco-friendly eggshell meal as a source of Ca increased the milk yield by up to 100%. The intake of dry matter and milk quality, such as pH, density, CP, and P, had a similar effect on commercial minerals. Eggshell meal can substitute commercial mineral supplements in Holstein Friesian dairy cows' diets. This approach increases milk yield and Ca content while reducing eggshell waste. It promotes environmental sustainability and improves the dairy sector's efficiency.

Acknowledgment

The authors would like to express their sincere thanks to the rector of the Hasanuddin University through the Institute for Research and Community Services of the Hasanuddin University (LPPM-Hasanuddin University), for supporting this study. The authors would also like to express their gratitude thanks to the dairy farmer group, *Tani Sipatuo*, local stakeholders in Enrekang Regency-South Sulawesi, and all contributors for accomplishing this study.

Funding Information

This study was funded by Institute for research and Community Services of the Hasanuddin University (LPPM-Hasanuddin University) through fundamental collaborative research program no. 00323/UN4.22/PT.01.03/2023.

Author's Contributions

Ambo Ako, Renny Fatmyah Utamy and Hasbi Hasbi: Conceived and designed the experiments, performed the field experiments, analyzed data, and wrote the paper.

Muhammad Irfan Said: Conceived and designed the experiments, performed the field experiments, performed analyzed data.

Muhammad Hatta, Nurul Sulfi Andini, Lizah Khairani, Andi Ni'matul Churriyah, Khaerunnisa Khaerunnisa, Andi Arif Rahman and Silvi: Performed the field experiments and data tabulation.

Rara Mufliha: Performed the field experiments and analyzed data.

Zyahrul Ramadan and Purnama Isti Khaerani: Performed the data tabulation and wrote the paper.

Ethics

Ethical consideration No. 470/UN4.6.4.5. 31/PP36/2023.

References

Aditya, S., Stephen, J., & Radhakrishnan, M. (2021). Utilization of Eggshell Waste in Calcium-Fortified Foods and Other Industrial Applications: A Review. *Trends in Food Science and Technology, 115*, 422-432. https://doi.org/10.1016/j.tifs.2021.06.047

Ahmed, T. A. E., Wu, L., Younes, M., & Hincke, M. (2021). Biotechnological Applications of Eggshell: Recent Advances. *Frontiers in Bioengineering and Biotechnology, 9*, 675364. https://doi.org/10.3389/fbioe.2021.675364

Aminah, S., and Meikawati, W. (2016). Calcium Content and Flour Yield of Poultry Eggshell with Acetic Acid Extraction. *UMS*, 49-53. http://hdl.handle.net/11617/7741

Azzumar, M., Khairiyati, L., Munir, M., Syahadi, M., Sardjono, H., Faisal, A., Perangin-Angin, W. K., Yayienda, N. F., Amalia, H., & Chotimah Alwahid Setiawan, A. K. (2022). Software Development and Its Validation for Semi-Automatic Measurement of Multifunction Calibrator. *International Journal on Electrical Engineering and Informatics*, *14*(1), 171-183. https://doi.org/10.15676/ijeei.2022.14.1.11

Baláž, M., Boldyreva, E. V., Rybin, D., Pavlović, S., Rodríguez-Padrón, D., Mudrinić, T., & Luque, R. (2021). State-of-the-Art of Eggshell Waste in Materials Science: Recent Advances in Catalysis, Pharmaceutical Applications and Mechanochemistry. *Frontiers in Bioengineering and Biotechnology, 8*, 612567. https://doi.org/10.3389/fbioe.2020.612567

Burezq, H. A. (2021). Utilization of Eggshell as Valuable Products for Sustainable Ecosystem and Agriculture. *Poultry Science Journal*, *9*(2), 147-165. https://doi.org/10.22069/PSJ.2021.19210.1699

Borges, R., Giroto, A. S., Klaic, R., Wypych, F., & Ribeiro, C. (2021). Mechanochemical synthesis of eco-friendly fertilizer from eggshell (calcite) and KH_2PO_4. *Advanced Powder Technology*, *32*(11), 4070-4077. https://doi.org/10.1016/j.apt.2021.09.013

Dong, L., Li, Y., Chen, Q., Liu, Y., Qiao, Z., Sang, S., Zhang, J., Zhan, S., Wu, Z., & Liu, L. (2023). Research Advances of Advanced Glycation end Products in Milk and Dairy Products: Formation, Determination, Control Strategy and Immunometabolism Via Gut Microbiota. *Food Chemistry*, *417*, 135861. https://doi.org/10.1016/j.foodchem.2023.135861

Duplessis, M., & Royer, I. (2023). Mini-Review: The Importance of an Integrated Approach to Assess Trace Mineral Feeding Practices in Dairy Cows. *Frontiers in Animal Science*, *4*, 1155361. https://doi.org/10.3389/fanim.2023.1155361

Eltahir, H. A., Ali, H. A., Mohammed, F. A., Mohammed, H., Mohamed, A., Eltgani, O. O., Yahia, N. S., Burma, A. A., & Hassan, Y. M. (2024). A Survey on Major Infertility Causes in Crossbred Dairy Cattle Farms in Nyala City-South Darfur State-Sudan. *American Journal of Zoology*, *7*(1), 6-11. https://doi.org/10.11648/j.ajz.20240701.12

Gómez-Alvarez, L. M., & Zapata Montoya, J. E. (2024). Effect of Fortification with $CaCO_3$ Nanoparticles Obtained from Eggshell on the Physical and Sensory Characteristics of Three Food Matrices. *Heliyon*, *10*(2), e24442. https://doi.org/10.1016/j.heliyon.2024.e24442

Gul, F., Amin, H., Naz, S., Khan, M. T., Alhidary, I., Khan, R. U., Pugliese, G., & Tufarelli, V. (2024). Evaluation of Blood Minerals and Oxidative Stress Changing Pattern in Prepartum and Postpartum Achai and Holstein Friesian Dairy Cows. *Reproduction in Domestic Animals*, *59*(1), e14525. https://doi.org/10.1111/rda.14525

Hasniar, H., Malesi, L., & Nafiu, L. O. (2021). Kualitas Telur Ayam Kampung yang Diberi Pakan Campuran Tepung Kulit Ari Biji Kedelai (*Glycine max*) Fermentasi Berbeda. *Jurnal Ilmiah Peternakan Halu Oleo*, *3*(4), 374-378. https://doi.org/10.56625/jipho.v3i4.21097

Hassan, N. M. M. (2015). Chicken Eggshell Powder as Dietary Calcium Source in Biscuits. *World Journal of Dairy and Food Sciences*, *10*(2), 199-206. https://doi.org/10.5829/idosi.wjdfs.2015.10.2.1152

Hunton, P. (2005). Research on Eggshell Structure and Quality: An Historical Overview. *Brazilian Journal of Poultry Science*. *7*: 67-71. https://doi.org/10.1590/S1516-635X2005000200001khair

International, A., & Latimer Jr. G. W. (2005). *Official Methods of Analysis* (18th Ed., Vol. *3*). *Oxford University Press*.

Lean, I. J., & Golder, H., M. (2023). Pasture Minerals for Dairy Cattle. *Veterinary Clinics of North America: Food Animal Practice*, *39*(3), 439-458. https://doi.org/10.1016/j.cvfa.2023.05.003

Liu, W., Tang, C., Cai, Z., Jin, Y., Ahn, D. U., & Huang, X. (2023). The Effectiveness of Polypeptides from Phosvitin and Eggshell Membrane in Enhancing the Bioavailability of Eggshell Powder Calcium and its Accumulation in Bones. *Food Bioscience*, *51*, 102257. https://doi.org/10.1016/j.fbio.2022.102257

Nandhini, K., & Karthikeyan, J. (2022). Effective Utilization of Waste Eggshell Powder in Cement Mortar. *Materials Today: Proceedings*, *61*, 428-432. https://doi.org/10.1016/j.matpr.2021.11.328

Okpanachi, U., Yusuf, K. A., Ikubaje, M. K., & Okpanachi, G. C. A. (2021). Effects of Egg Shell Meal on the Performance and Haematology of Layers and Their Egg Quality. *African Journal of Science, Technology, Innovation and Development*, *13*(1), 89-96. https://doi.org/10.1080/20421338.2020.1838111

Sabir, P. S., & Abbas, K. A. (2023). Effect of Strontium Ranelate and Cerium Oxide Addition in the Diet on Egg Production and Eggshell Quality in Laying Hen. *The Indian Journal of Animal Sciences*, *93*(1), 77-81. https://doi.org/10.56093/ijans.v93i1.128219

Sathiparan, N. (2021). Utilization Prospects of Eggshell Powder in Sustainable Construction Material-A Review. *Construction and Building Materials*, *293*, 123465. https://doi.org/10.1016/j.conbuildmat.2021.123465

Singh, A., Kelkar, N., Natarajan, K., & Selvaraj, S. (2021). Review on the Extraction of Calcium Supplements from Eggshells to Combat Waste Generation and Chronic Calcium Deficiency. *Environmental Science and Pollution Research*, *28*, 46985-46998. https://doi.org/10.1007/s11356-021-15158-w

Stocco, G., Summer, A., Malacarne, M., Cecchinato, A., & Bittante, G. (2019). Detailed Macro- and Micromineral Profile of Milk: Effects of Herd Productivity, Parity, and Stage of Lactation of Cows of 6 Dairy and Dual-Purpose Breeds. *Journal of Dairy Science*, *102*(11), 9727-9739. https://doi.org/10.3168/jds.2019-16834

Yang, D., Zhao, J., Ahmad, W., Nasir Amin, M., Aslam, F., Khan, K., & Ahmad, A. (2022). Potential use of Waste Eggshells in Cement-Based Materials: A Bibliographic Analysis and Review of the Material Properties. *Construction and Building Materials*, *344*, 128143. https://doi.org/10.1016/j.conbuildmat.2022.128143

Zhu, L., Ma, M., Ahn, D. U., Guyonnet, V., Wang, L., Zheng, Y., He, Q., Xiong, H., & Huang, X. (2022). Hatched Eggshell Membrane Can Be a Novel Source of Antioxidant Hydrolysates to Protect against H2O2-Induced Oxidative Stress in Human Chondrocytes. *Antioxidants*, *11*(12), 2428. https://doi.org/10.3390/antiox11122428