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The Impact of Macrominerals (Calcium and Magnesium) on Feed Intake, Average Daily Gain and Feed Efficiency in Sheep

Kusuma Adhianto*, Feni Pristiawati, Muhtarudin and Syahrio Tantalo

Department of Animal Science, Faculty of Agriculture, University of Lampung, Jl. Prof. Dr. Soemantri Brojonegoro No.1 Gedong Meneng Bandar Lampung 35145, Lampung Province, Indonesia
***Corresponding author:** kusuma.adhianto@fp.unila.ac.id

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ABSTRACT

The objective of this study is to assess the impact of supplementing minerals (calcium and magnesium) in the diet on the feed intake, average daily gain (ADG) and feed efficiency of sheep. The investigation was conducted at the Animal Husbandry Department, Agriculture Faculty, Lampung University, located in Bandar Lampung. This study employed a Randomized Block Design (RBD) with 3 treatments and 5 groups, and involved a total of 15 male sheep. The treatments were P0: 100% basal feed; P1: P0 + Ca Cl_2 25.7mL/kg BK and Mg Cl_2 6.5mL/kg feed; and P2: P0 + organic mineral supplementation diet. The results of the research on feed intake were P0 1,009.8; P1 1,023.1; and P2 1,049.6 grams of BK/day, and body weight gain (PBT) was P0 69.3; P1 66.3; and P2 118.3 gram/day, and feed efficiency of P0 6.8%; P1 6.4% and P2 11.4%. The research results showed that giving minerals (Ca and Mg) had no effect in feed intake, it affects ADG and feed efficiency.

Key words: Average daily gain, Feed intake, Feed efficiency, Macro minerals and Sheep

INTRODUCTION

Livestock productivity can be evaluated based on the performance and physical characteristics of the animals, which are impacted by a combination of genetic makeup and environmental conditions. Efforts to enhance and sustain livestock productivity involve optimizing essential nutrients for livestock, such as the inclusion of supplementary feed ingredients containing calcium (Ca) and magnesium (Mg) minerals. Enhancing the nutritional content of feed can hasten the growth, bolster the immune system, and enhance the physical condition of livestock. Specifically, calcium is indispensable for bone growth, muscle function, and metabolic processes, whereas magnesium is vital for enzymatic activity, nerve function, and energy metabolism. An appropriately formulated mineral supplementation plan not only improves feed efficiency and weight gain, but also enhances reproductive performance and the general welfare of animals. Hence, ensuring adequate mineral nutrition is essential for maintaining sustainable and productive livestock production systems (Pinotti et al. 2021; Kovács et al. 2023; Ataollahi et al. 2023).

In the digestive tract, microbes need food substances, including minerals, for their growth. Macro minerals in the livestock's digestive system interact positively or negatively with fat, protein and other organic materials so that the minerals are immediately excreted in the feces. The minerals Ca and Mg, in addition to stimulating the growth of rumen microbes, also play a role in the activity of metabolic enzymes related to energy, thereby impacting livestock productivity. Therefore, by providing the macro minerals Ca and Mg in the feed, it is hoped that it can improve the performance of sheep, which includes increasing body weight, intake and feed efficiency (McLoughlin et al. 2020; Carrillo-Muro et al. 2023; Herbster et al. 2023).

The research on the administration of macro minerals such as calcium (Ca) and magnesium (Mg) in sheep feed is of high importance given the crucial role of these minerals in supporting the performance and health of livestock. Calcium and magnesium are essential nutrients that cannot be synthesized by the animal body and must be supplied through feed. A deficiency in either one or both of these nutrients can lead to disturbances in metabolism, reduced productivity and significant health risks in sheep (Underwood & Suttle 1999; Khan et al. 2007; Xiong et al. 2024; Wang et al. 2021).

In tropical regions, sheep that are raised often consume forage with varying mineral content, which may not always meet their essential bodily needs. In this situation, it is crucial to supplement with calcium and magnesium in

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order to optimize rumen microbial activity, support fiber digestion and enhance feed conversion efficiency. This research aims to provide relevant scientific data on the optimal doses of both minerals in sheep feed formulations (Suttle 2010; Jin et al. 2023; Lin et al. 2024: Zhang et al. 2022; Laverell et al. 2025).

MATERIALS AND METHODS

Materials

The equipment needed in this research was 15 individual type cages, feed and drink containers, hanging scales with a capacity of 50kg, digital scales for weighing feed, shovels, buckets, tarpaulins, hoes, broomsticks, sacks, plastic, and stationery. Meanwhile, the materials used in this research were 15 male sheep, cassava leaf silage, onggok, copra cake, bran, water, lysine, CaCl2, MgCl2 and drinking water to meet water needs, which were provided *ad libitum*.

Method

This research was conducted using 15 sheep using the Randomized Block Design (RAK) method. Animals were grouped into five groups based on body weight as replicates. The treatments used are:

P0: Basal Feed (Table 1) 100%

P1: P0+CaCl2 (25.7mL/kg feed) and MgCl2 (6.5mL/kg feed)

P2: P0 + Ca *lysinat* (25.7mL/kg feed) and Mg *lysinat* (6.5mL/kg feed)

The study had two stages: the preliminary stage and the data collection stage. The initial phase was a 14-day period to get the animals used to the new feed treatment. For 60 days, data was gathered. The animals were fed three times a day at 08:00AM, 01:00PM and 05:00PM, and provided with water *ad libitum*.

Observed variables

The variables observed in this study were feed intake, ADG, and feed efficiency. The feed intake data was taken every morning before feeding for 60 days. Body weights of sheep were recorded every 30 days, and efficiency was determined from the ratio of the feed consumed to the body weight gain produced by sheep.

Data Analysis

The data were analyzed using ANOVA at a 5% significance level and if the results show significance ($P<0.05$) or very significance ($P<0.01$), the LSD test was carried out (Susilo 2013).

RESULTS AND DISCUSSION

Effect of treatment on feed intake in sheep

Feed intake is the amount of feed consumed by livestock and greatly influences livestock productivity, namely increase in body weight. The average yield of feed intake during 60 days of maintenance ranges from 1,009.8 to 1,049.6. Feed intake from the treatment of adding Ca and Mg minerals to male sheep can be seen in Table 2.

The results of the analysis of variance in Table 2 show that the treatment given had no significant effect ($P>0.05$) on the feed intake of sheep. The average feed intake of sheep (grams DM/head/day) in each treatment was 1,009.8±33.6 (P0), 1,023.1±64.0 (P1) and 1,049.6±123, 1 (P2). Feed intake in each treatment had relatively the same results because there were no differences in the feeds used. This is supported by Hernaman statement et al. (2008) that there is no difference in the value of feed intake which means that the livestock likes the feed given or has the same level of preference. The lowest mean feed intake was in the control treatment (100% basal feed) namely 1,009.8 (g DM/head/day), while the highest value was in treatment 2 (100% basal feed + Ca minerals *lysinat* and Mg *lysinat*) namely 1,049.6 (g DM/head/day). According to Luthfi et al. (2022), there are several factors that can influence high and low feed intake, namely feed factors which include digestibility and palatability, livestock factors which include age, breed, health condition and gender of the animal.

Table 1: The composition (%) of basal diet ingredients

Feed Ingredients	Nutritional Content of Ingredients				
	DM	CP	CF	EE	Ash
Cassava leaf silage	23.00	21.07	23.55	11.43	6.03
Copra cake	92.84	21.06	14.52	15.87	7.01
Onggok	94.39	2.79	15.63	4.10	1.71
Bran	91.54	11.28	9.50	9.31	8.64

DM: Dry Material; CP: Crude Protein; CF: Crude Fiber; and EE: Ether extract; Source: Analysis findings from the Animal Nutrition and Forage Laboratory, Animal Husbandry Department, Agriculture Faculty, Lampung University, 2023.

Table 2: Effect of treatment on feed intake in sheep

Group	Feed Treatment		
	P0	P1	P2
	----------(g DM/head/day) ----------		
1	1,047.4	1,027,00	876.1
2	993.9	936.2	994.3
3	963.5	1061.8	1,088.3
4	1,036.5	1,101.5	1,082.00
5	1,008.00	989.1	1,207.1
Average	1,009.8±33.6	1,023.1±64.0	1,049.6±123.1

P0: Basal Feed 100%; P1: P0 + CaCl2 (25.7mL/kg feed) and MgCl2 (6.5mL/kg feed); P2: P0 + Ca *lysinat* (25.7mL/kg feed) and Mg *lysinat* (6.5mL/kg feed).

According to Fadilla et al. (2020), Bioprocesses in the rumen are greatly influenced by the microbes in the rumen. The maximum rumen microbial growth rate is achieved when the supply of all precursor nutrients is available in optimum concentrations. Supplementation or additional nutrition is needed to support the growth of microbes in the rumen to utilize the feed consumed. With the addition of the macro minerals Ca and Mg, bioprocesses in the rumen and post-rumen become more optimal and the metabolism of food substances increases. The addition of the macro mineral magnesium (Mg) in the feed aims to meet the needs of the livestock's body. Adequate mineral needs will increase livestock appetite. If livestock lack the mineral Mg in their bodies continuously, it will result in decreased appetite, reproductive disorders and decreased production (Robinson et al., 1989).

In treatment P2, which consisted of a 100% basal diet supplemented with organic calcium lysinate and magnesium lysinate, feed intake tended to be higher compared to other treatments. Elita (2006) explains that

feed intake in livestock can influence palatability, energy levels, protein and amino acid concentrations, forage composition, environmental temperature, growth and lactation as well as the size of the body's metabolism. The presence of amino acids in the form of lysine will help maximize the process of carbohydrate metabolism in the body into energy so that it will result in fast hunger due to the fast digestibility of feed, making livestock continue to consume feed.

Livestock under normal circumstances will consume a limited amount of feed to meet basic needs. Feed intake in this study is within the normal range according to the 2006 NRC opinion in Luthfi et al. (2022), sheep with a body weight of 20-30kg during the fattening period can consume dry matter of 690-1,240 g/head/day. Tanuwiria (2013) also added that rams aged 9-12 months can consume dry matter (DM) feeds of 493-750g/head/day which comes from feed with added minerals. Consuming large amounts of feeds shows that the amount of nutrients absorbed for basic living needs, production and reproduction increases, thereby causing an increase in sheep growth.

Effect of treatment on ADG of sheep

Body weight gain is an indicator of success for evaluating the feed given to livestock, because this growth is obtained from the utilization of the food substances provided. The value of weight gain from the treatment of providing minerals (Ca and Mg) in the feed for male sheep can be seen in Table 3.

Table 3: Effect of treatment on ADG (g/head/day) in sheep

	Feed Treatment		
Group	P0	P1	P2
1	120.0	123.3	130.0
2	66.7	30.0	103.3
3	73.3	80.0	83.3
4	63.3	73.3	125.0
5	23.3	25.0	150.0
Average	69.3±34.4[a]	66.3±40.4[a]	118.3±25.7[b]

Values (mean+SD) bearing different alphabets in a row differ significantly (P<0.05). P0: Basal Feed 100%; P1: P0 + CaCl2 (25.7mL/kg feed) and MgCl2 (6.5mL/kg feed); P2: P0 + Ca *lysinat* (25.7mL/kg feed) and Mg *lysinat* (6.5mL/kg feed).

Based on the analysis of variance in Table 3, which was carried out, the results showed that the provision of minerals (Ca and Mg) in the feed had a significant effect (P<0.05) on the daily body weight gain of sheep. The average results of this study showed that all treatments showed an increase in body weight. The results of further LSD tests in the mineral (Ca and Mg) treatment showed that treatment P0 was not significantly different from P1. Then P2 treatment was significantly different from treatment P0 and P1.

The effect of mineral addition on livestock productivity is a reflection of increased intake, rumen microbial fermentation activity and food digestibility. Body weight gain in ruminant livestock is also greatly influenced by the quality and quantity of feed provided, because the level of feed intake is directly proportional to body weight. In treatment P1, the addition of minerals in inorganic form appeared to hinder the digestive process in the sheep's rumen. Inorganic minerals are less bioavailable and more difficult to metabolize in the rumen, which may have contributed to a decrease in body weight during the 30-day study period. Furthermore, the sheep experienced physiological stress likely caused by the relatively high environmental temperatures in the pen. Luthfi et al. (2022) stated that weight gain or weight loss is greatly influenced by how much or how little livestock consumes feed.

The provision of macro minerals to livestock productivity reflects an increase in feed intake, microbial fermentation activity in the rumen, and digestibility of food substances in the animal's body. The adequate calcium (Ca) content in the feed is able to function optimally in the formation of bones and teeth. The role of hormones and growth factors is also greatly supported by the supply of calcium in the body. Apart from that, the mineral magnesium (Mg) also has a very important role in livestock growth because it has biological functions, namely energy metabolism, muscle contraction, enzymatic function and protein synthesis. The increase in body weight of sheep is greatly influenced by the balance of nutrients contained in the feed provided.

ADG in treatment P2 was more optimal compared to other treatments due to the provision of organic minerals (Ca *lysinat* and Mg *lysinat*) which contains the amino acid in the form of lysine and can also be seen from the feed intake in treatment P2 which has a higher intake value than other treatments. According to Mashudi (2014), lysine functions as a limiting amino acid for microbial protein synthesis for the growth of ruminants. By adding lysine, it can improve feed quality because most feed proteins are poor in lysine, giving minerals in the form of organic minerals can increase availability so that they are better absorbed in the livestock's body (Muhtarudin et al. 2003; Adhianto et al. 2018).

Lysine is one of the essential amino acids that plays a crucial role in the metabolism of ruminant animals, particularly in supporting the synthesis of microbial proteins in the rumen. According to the National Research Council (NRC 2001), lysine is required as the first or second limiting amino acid, depending on the composition of the ration, in order to ensure that rumen microbes have adequate nitrogen intake to develop and function optimally.

In the rumen, microbes utilize non-protein nitrogen (NPN) and amino acids such as lysine to synthesize microbial protein. Lysin plays a contributing role as a nitrogen source directly involved in the formation of structural proteins in microbes, enzymes, and other essential metabolites. According to Dewhurst et al. (2000), these microbial proteins subsequently serve as the primary source of protein for ruminant animals when digested in the small intestine after passing through the rumen.

In addition, lysin plays a role in supporting rumen activity by enhancing the efficiency of fiber fermentation. This occurs because lysin facilitates the synthesis of enzymes that are essential for the decomposition of organic materials, such as cellulose and hemicellulose, by rumen microorganisms. This efficiency not only enhances energy availability but also supports microbial balance in the rumen (Bach et al. 2005).

The insufficient presence of lysine in the diet may restrict the ability of microbes to synthesize proteins optimally, thereby reducing feed efficiency and livestock production performance. Therefore, supplementation of lysine, whether in the form of protein bypass or protected

lysine from rumen degradation, is often conducted to ensure the metabolic needs of livestock are met (Lapierre et al. 2005).

ADG in this study was within the normal range, the average daily body weight gain of sheep with improvements in feed technology was able to reach 57-132g/head (Prawoto et al. (2001); Aisyah et al. (2024) stated that the ADG in the study was also relatively high and showed an increase in body weight at each weighing period, because sheep are incentive reared in individual pens. This is supported by Sudarmono (2003) who stated that there was a daily increase in body weight in sheep of 50 to 150g/day with intensive rearing in individual pens.

Effect of treatment on feed efficiency in sheep

Feed efficiency is defined as the amount of feed utilization by the animal's body to produce an increase in body weight (Adriani 2009). The feed efficiency values from the treatment of adding Ca and Mg minerals to male sheep can be seen in Table 4.

Table 4: Effect of treatment on feed efficiency (%) in sheep

	Feed Treatment		
Group	P0	P1	P2
1	11.5	12.0	14.0
2	6.7	3.2	10.4
3	7.6	7.5	7.7
4	6.1	6.7	11.6
5	2.3	2.5	12.4
Average	6.8±3.3[a]	6.4±3.8[a]	11.4±2.6[b]

Values (mean+SD) bearing different alphabets in a row differ significantly (P<0.05). P0: Basal Feed 100%; P1: P0 + CaCl2 (25.7mL/kg feed) and MgCl2 (6.5mL/kg feed); P2: P0 + Ca *lysinat* (25.7mL/kg feed) and Mg *lysinat* (6.5mL/kg feed).

Based on the analysis of variance in Table 4, the results showed that the provision of minerals (Ca and Mg) in the feed had a significant effect (P<0.05) on the efficiency of the sheep feed. The average feed efficiency of male sheep in each treatment was 6.8±3.3(P0), 6.4±3.8(P1), and 11.4±2.6(P2). The results of further LSD (Least Significant Difference) tests in the mineral (Ca and Mg) treatment showed that treatment P0 was not significantly different from P1. Then treatment P2 was significantly different from treatment P0 and P1. Sodikin et al. (2013) stated that factors that can influence the efficiency value of livestock feeds in producing meat are breed of livestock, composition and level of production as well as nutritional value of feed. Apart from that, there is also the age of the livestock, feed quality, and body weight which are factors in the size of the livestock's feed efficiency value. Tarmidi (2015) also added that apart from feed intake and body weight gain, the quality and quantity of the feed also greatly influences the efficiency value (Tarmidi 2015; Cantalapiedra-Hijar et al. 2018).

Treatments P0 and P1 showed low feed efficiency results when compared with P2 because it has a fairly high level of intake but has not been able to produce appropriate body weight gain. The amount of nutrients needed and the ability of livestock to consume feeds is very dependent on the livestock's body weight. The efficiency value in P2 is characterized by a fairly high amount of feed intake and results in the greatest increase in body weight. This efficiency shows the size of the livestock's use of feeds for use in their bodies. The increase in efficiency values occurs due to the utilization of nutrients in metabolic processes in livestock body tissues. The addition of amino acids in the form of lysine results in better feed quality so that it can produce quite good body weight gain by maximizing feed intake.

The feed efficiency value for sheep ranges from 6.78–13.72% (Mathius et al. 2001; Ekawati et al. 2014). The feed efficiency values in treatments P0 and P2 are within the normal range, while P1 produces lower feed efficiency. However, the results of this research are still lower than the results of Muktiani's research et al. (2013) with daily body weight gain of sheep fed vegetable waste silage with added minerals ranging from 90-138g/day with feed efficiency ranging from 17.33-22.09%.

Conclusion

Based on the findings of this study, it can be concluded that the supplementation of calcium (Ca) and magnesium (Mg) in sheep diets did not significantly influence feed intake. However, when provided in organic forms (Ca-lysinate and Mg-lysinate), these minerals contributed to improved body weight gain and feed efficiency, indicating their potential role in enhancing growth performance in sheep under tropical conditions.

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Conflict of Interest: The authors have declared that there is no conflict of interest.

Data Availability: The datasets generated during the current study are available from the corresponding author upon reasonable request.

Ethics Statement: This study was conducted in accordance with the ethical standards of the institutional and/or national research committee and its later amendments or comparable ethical standards. Ethical approval was obtained from the Ethical Review Committee, Faculty of Agriculture, University of Lampung, with approval number 108A.UN26.14/TU.00.2024.

Author's Contribution: Kusuma Adhianto was responsible for conceptualization, methodology, project administration, and writing – review and editing. Feni Pristiawati contributed to data curation, formal analysis, investigation, and writing – original draft. Muhtarudin provided resources, supervision, validation, and participated in writing – review and editing. Syahrio Tantalo contributed to software, visualization, data curation, and writing – original draft. All authors have read and approved the final version of the manuscript.

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