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Bioavailability of Calcium, Phosphorus and Quality of Milk Components of Etawa Cross-breed Goats Fed Banana Peels

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ABSTRACT

This study investigates the bioavailability of essential minerals, specifically calcium (Ca) and phosphorus (P), along with the impact on milk quality components in Etawa Cross-breed goats when supplemented with banana peels in their diet. This study used a randomized block design with 4 treatments. Sixteen Etawa crossbreed goats fed a ration consisting of energy in the form of 68% TDN and crude protein 12%. The treatment was using banana peels at various levels in the diet 0, 0.5, 10 and 15%. The results showed that eating banana peels increased the amount of dry matter consumed (2.97-3.13% of body weight). Bioavailability of Ca, and P were not different (P>0.05) among the four treatments. Milk components were also not significantly different (P>0.05), except for milk lactose content. Milk lactose was increased (P<0.01) with increasing use of banana peels in ration up to 15%. Ratio of calcium to phosphorus was 1.43:1-1.48:1. In conclusion, bioavailability of calcium and phosphorus in lactating goats can be maintained by feeding 15% banana peel in the ration with a value of 57.64 and 49.37% respectively, and with a goat's milk fat content of 5.21%; milk lactose 4.00% and milk protein 3.10%. This information is required in order to utilize banana peels as an energy source in ruminant diets without disrupting the process of mineral absorption and quality of milk components.

Key words: Agricultural by-product, Dairy goat, Mineral bioavailability, Milk quality.

INTRODUCTION

Calcium (Ca) and phosphorus (P) are essential nutrients for lactating dairy goat. If the need of these minerals in lactating goats are not met, then these minerals will be mobilized from the bones to meet their needs (Haenlein 1980). Bioavailability is the percentage of nutrient in a diet that is absorbed and utilized for metabolic process (Drago 2017). Calcium bioavailability is the ratio of available calcium to the amount of calcium consumed (Ningsih and Sanjaya 2022). It is the percentage of nutrient in a diet that is absorbed and utilized for metabolic process (Theobald 2005). The percentage of calcium bioavailability is determined based on the amount of calcium minerals in the feed consumed and the amount of calcium minerals in the excreted feces. Essential minerals must be incorporated through the diet. They have many functions in the body and if not provided in sufficient amounts, deficiencies are manifested through specific and nonspecific symptoms (Drago 2017). Ca is absorbed in ionic form (syahrial and Handayani 2020). Absorbable Ca must be in a readily available form and remain in solution when dissolved in gastric acid (Gueguen and Pointillart 2000). High Ca bioavailability can increase Ca absorption in the body (Ningsih and Sanjaya 2022).

The Etawa crossbreed goat is a dual-purpose type of livestock that is easy to adapt and has high milk production, making it a great potential to be utilized. Etawa crossbreed goats can produce one liter of milk/day/head (Arief et al. 2023a, 2023b, 2023c). The productivity of livestock is largely influenced by feed. The most common limiting factor in small ruminant livestock, goats, is energy. Lack of energy results in decreased milk production in goats. During lactation, it's necessary to feed high-energy rations. Indeed, lactating requires the most energy. An equally important factor than energy is the availability of minerals for lactating goats. Minerals and vitamins are important components of dairy goat nutrition, and their requirements can be affected by the physiological growth state of the goat (growth, pregnancy, and lactation) (Hart 2020).

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Mineral deficiencies in dairy goats can have detrimental health effects. Calcium deficiency in dairy goats can lead to reduced milk production and cause parturient paresis (milk fever). Phosphorus deficiency can result in slow growth, an unthrifty appearance and occasionally a depraved appetite. The calcium to phosphorus ratio should be maintained between 1:1 and 2:1 to avoid predisposition for urinary calculi.The recommended calcium level for the metabolic function of goats is a minimum of 0.3% and a maximum of 0.8% (Hart 2020). Phosphorus is another essential mineral present in goat milk. It works in conjunction with calcium to support the development and maintenance of bones and teeth. Phosphorus also has important functions in energy metabolism, cellular signaling, and the formation of nucleic acids and proteins.

Bananas are tropical plants belonging to the Musaceae family (Anhwange 2008; Kavitha and Manonmani 2020). The amount of banana peel produced is 40% of the weight of fruit and this is waste that has not been utilized optimally (Youssef et al. 2018; Sial et al. 2019). The banana production in Indonesia reached 8.18 million tons in 2020. This number increased 12.39% from 7.28 million tons in 2019 and in West Sumatra, banana production reached 142,034 tons in 2020 (Central Bureau of Statistics (Indonesia), 2021). Banana peels can be used as an energy source because they contain high carbohydrates with total carbohydrates ranging from 64.6-72.8%. (Bakar et al. 2018). Hasan et al. (2018) revealed that banana peels also contain important minerals that livestock need, both macro and micro minerals, namely: calcium (59.10±0.85mg/ 100g), phosphorus (211.30±1.24mg/100g), iron (47.00±1.26mg/100g), magnesium (44.50±0.08 mg/100g), sodium (115.10±0.26mg/100g). Because banana peel contains large amount of nutrients and minerals, it has the potential to be included in diet formulation. Besides being rich in nutrients, banana peels also contain the anti-nutritional factors: hydrocyanic acid / HCN (1.33mg/g) (Pimentel et al. 2017) which can disrupt the fermentation process in the rumen (Agustin et al. 2021) and disrupt the respiration process in lactating dairy cattle (Agustin et al. 2020). Other anti-nutritional factors found in banana peel are tannins, oxalate and phytate (Abou-Arab and Abu-Salem 2017).

Ca and P ratio is a crucial factor in animal nutrition, there is limited research on the impact of banana peel supplementation on these essential minerals. This study explores the utilization of banana peels as a component of the dietary ration for dairy goats and investigates the bioavailability of calcium and phosphorus from this unconventional feed source. Additionally, it assesses the impact of banana peel inclusion on milk quality and milk production in dairy goats. This research is needed because there is not much information about the bioavailability of calcium and phosphorus minerals in Etawa crossbreed dairy goats. This research contributes to the provision of alternative feed for ruminant livestock, especially lactating dairy goats.

MATERIALS AND METHODS

Ethical Aproval

This experiment has referred to research ethics using livestock based on the Republic of Indonesia government law number 18 of 2009 (Section 66), which addressed animal keeping, raising, killing and proper treatment and care. This experiment also followed the Guide for the Care and Use of Agricultural Animals in Research and Teaching outlined by Federation of Animal Science Societies (American Dairy Science Association 2020).

Study Period and Experimental Site

This research was carried out at Andalas University's Ruminant Laboratory of Animal Science Faculty from June to November 2023.

Experimental Design

This research used a randomized block design with four treatments (Gomez and Gomez 1984). Sixteen Etawa crossbreed goats fed a ration consisting of energy in the form of 68% TDN and crude protein 12%. The treatments using banana peels at various levels in the diet were 0, 5, 10, and 15%. Grouping of goats was based on milk production. Grouping based on milk production. Table 1 provides an explanation about composition of the feed ingredients in goat ration.

Table 1: Composition of the feed ingredients in goat ration

Feed Ingredients (%)	Treatment			
	Diet 1	Diet 2	Diet 3	Diet 4
Field grass	60	55	50	45
Banana peel	0	5	10	15
Tofu dregs	32	32	32	32
Rice straw	5.2	5.2	5.2	5.2
Ground corn	2.4	2.4	2.4	2.4
Mineral	0.4	0.4	0.4	0.4
Total	100	100	100	100

Research Implementation

The research was carried out in three periods: adaptation, preliminary and data collection period. The preliminary period aims to eliminate the influence of previous feed, namely for 14 days. The data collection period was carried out for 5 days. Data collected were feed consumption, milk production and total feces. Fecal samples were taken as much as 10% of the total feces per day.

Data Collection

The feces were collected for five days in the collection period. During the collection period, samples of rations or feed ingredients as well as samples of milk produced every day were also collected. The number of milk samples taken was 10% of the total milk/day.

Samples Analysis

The forage samples provided and the feces samples were dried in the hot sun, then ground and filtered with a sieve size of 2mm. The analyses were conducted according to the methods described by the Association of Official Analytical Chemists (AOAC 2016) to determine dry matter (DM; method 967.03), ash (method 942.05), crude protein (CP; method 981.10), ether extract (EE; method 920.29) and Neutral detergent fiber (NDF) was determined according to Van Soest et al. (1991). Fecal sample were used to determin bioavailability of Ca and P. A milk sample was stored at 4°C for analysis of lactose, protein, fat, total solid (TS), soli-non-fat (SNF) content.

Data Evaluation

Statistical analysis of the data was made by using the analysis of variance. Differences in effects among treatments were tested using Duncan's Multiple Range Test (Gomez and Gomez 1984).

RESULTS

Nutrients Content of the Diet

Table 2 provides information on the nutrients content of diet for lactating goat fed banana peel. The ration's protein content ranged from 12.17 to 12.32%, while its TDN level ranged from 67.96 to 68.49%. It is clear that the treatment rations have the same protein content and the same energy level. The calcium and phosphorus contents of all diets with some level of banana peel were also almost the same. Calcium levels range from 0.62 to 0.64%, while ration phosphorus levels range from 0.42 to 0.44%.

Table 2: Nutrients content of the ration using cassava peel

Nutrients Content (%)	Treatment: Banana peel in diet			
	0%	5%	10%	15%
Organic matter	89.12	89.03	88.93	88.84
Total digestible nutrients	67.96	68.13	68.31	68.49
Crude protein	12.32	12.27	12.22	12.17
Crude fat	4.94	5.21	5.48	5.76
Nitrogen free extract (NFE)	51.20	51.38	51.55	51.72
Ash	10.88	10.97	11.07	11.16
Neutral Detergent Fiber (NDF)	57.81	56.96	56.11	55.27
Calcium	0.64	0.64	0.62	0.62
Phosphorous	0.44	0.44	0.43	0.42
Lignin	4.19	4.06	3.94	3.81

Dry Matter Intake of Etawa Crossbreed Goat

The results in Table 3 show that dry matter intake (DMI) of rations ranged from 2.97-3.13% of body weight. The lowest dry matter consumption was found in the treatment without using banana peels in the ration, while the highest dry matter consumption was found when using 15% banana peels in the ration. There was a significant difference (P<0.05) in DMI among the four treatments. Dry matter intake based on kg per head per day ranged from 1.781 to 1.885kg/day.

Table 3: Average dry matter intake (% body weight) and (kg/head/day^{-1}) of lactating Etawa crossbreed goats fed banana peel in the diet (0-15%)

Banana peel in diet	Dry Matter Intake (DMI)	
	DMI (% body weight)	DMI (kg day^{-1})
0%	2.97a	1.781a
5%	3.03b	1.819b
10%	3.07c	1.847c
15%	3.13d	1.885d
SE	0.05	0.002

Different alphabets in the same column show a highly significant different (P<0.01) effect.

Bioavailability of Calcium (Ca) in Lactating Goats Fed Banana Peel

The results in Table 4 provides information about the amount of Ca consumed, Ca excreted in feces, Ca absorption and Ca bioavailability in lactating goats fed banana peels in the ration. The amount of Ca consumed ranges from 11.40 to 11.68g/head/day and these results indicate that there was no significant difference in the amount of Ca intake in lactating goats given banana peels.

In Table 4, it can be seen that calcium absorption ranges from 6.14 to 6.73g. Based on the results of statistical analysis, it is known that the use of banana peel in the ration up to 15% showed no significant different effect (P>0.5).

Calcium bioavailability values range from 53.85 to 57.64%. The highest value was obtained in the treatment of using 15% banana peel in the ration. The results of statistical analysis showed that the banana peel treatment had a significant effect (P<0.05) on bioavailability of Ca in lactating goats.

Table 4: Bioavailability of calcium of lactating goats fed banana peel

Parameters	Banana peel in diet				
	0%	5%	10%	15%	SE
DMI (kgday-1)	1.781a	1.819b	1.847c	1.885d	0.002
Ca intake (g)	11.40a	11.46a	11.45a	11.68a	1.55
Ca in feces (g)	5.26	5.20	4.90	4.95	0.21
Ca absorption (g)	6.14a	6.26a	6.55a	6.73a	0.22
Ca bioavaulabiliy (%)	53.84a	54.58a	57.22a	57.64a	1.83
Ratio Ca:P	1.45:1	1.43:1	1.44:1	1.48:1	

Means with different alphabets in a row show a highly significant different (P<0.01) effect.

Bioavailability of Phosphorus (P) in Lactating Goats Fed Banana Peel

The results in Table 5 provides information about the amount of P consumed, excreted phosphorus in feces, absorption and bioavailability of P in lactating goats fed banana peels in the ration. The amount of P consumed ranges from 7.84 to 8.00g per head per day, and these results indicate that there was significant difference (P<0.05) in the amount of P intake in lactating goats given banana peels.

In Table 5, it can be seen that P absorption ranges from 3.91 to 4.03g. Based on the results of statistical analysis, it is known that the use of banana peel in the ration up to 15% had no significant different effect (P>0.05). Bioavailability of P ranged from 49.37 to 50.32%. The lost value was obtained in the treatment of using 15% banana peel in the ration.

Table 5: Bioavailability of phosphorus of lactating goats fed banana peel.

Parameter	Banana peel in diet				
	0%	5%	10%	15%	SE
P intake (g)	7.84a	8.00d	7.94c	7.92b	0.01
P in feces (g)	3.89	3.97	3.93	4.01	0.67
P absorption (g)	3.95a	4.03a	4.01a	3.91a	0.51
P bioavailability (%)	50.32a	49.60a	49.47a	49.37a	0.46
Ratio Ca : P	1.45:1	1.43:1	1.44:1	1.48:1	

Different alphabets in the same row show a highly significant different (P<0.01) effect.

Quality of Milk Components in Lactating Goats Fed Banana Peel

In Table 6, it can be seen that the protein content of milk ranges from 2.99-3.10%. Feeding banana peel to lactating goats resulted in the highest protein content in the 15% banana peel treatment, while the lowest treatment was in the 5% banana peel treatment. The milk protein content in lactating goats showed that the results were not

significantly different (P>0.05) with different levels of banana peel in diet.

Table 6 also provides information about milk lactose levels. The lactose level in the milk of goats fed banana peel in their rations ranges from 3.27 to 4.00%. The highest lactose levels were found in the treatment using 15% banana peels in the ration, while the lowest lactose levels were found in the control treatment, without the use of banana peels. The results of statistical analysis showed that the banana peel treatment had a significant effect (P<0.05) on milk lactose. Besides the milk protein and milk lactose levels, Table 6 also shows the results of the goat's milk fat content. The fat content of goat's milk in this study ranged from 5.00 to 5.21%.

The highest milk fat content was found in the treatment using 15% banana peels in the ration, with a value of 5.21%, while the lowest milk fat content with a value of 5.01% was found in the control treatment, without the use of banana peels.

The total solid content of goat's milk ranged from 11.47 to 11.51% and the results of statistical analysis showed that there was no significant difference (P>0.05) due to the provision of 0 to 15% banana peel in the ration. The solid nonfat (SNF) in the milk of goats fed banana peel in their rations ranges from 3.27 to 4.00%. Based on the results of statistical analysis, the non-fat solid content of goat milk was not significantly different (P>0.05) from feeding banana peels in the ration.

Table 6: Milk quality of lactating goats fed banana peel

Milk quality	Banana peel in diet				
	0%	5%	10%	15%	SE
Milk yield (kg, 4% FCM)	1.29	1.2	1.19	1.31	0.35
Total solid (%)	11.49	11.47	11.51	11.49	0.04
Milk fat (%)	5.19	5.00	5.11	5.21	0.22
Solid nonfat (%)	6.30	6.47	6.40	6.28	0.21
Milk protein (%)	3.07	2.99	3.17	3.10	0.24
Milk lactose (%)	3.27a	3.7b	3.87c	4.00c	0.05

Different alphabets in the same row show a highly significant different (P<0.01) effect.

DISCUSSION

Dry Matter Intake of Lactating Etawa Crossbreed Goat Fed Banana Peel in Diet

The dry matter intake ranges from 1.781kg/head/day to 1.885kg/head/day with the highest intake found in the use of banana peels at 15% in the diet. In this study, the use of 15% banana peel in the ration was most preferred by lactating goats. This means that banana peels have high palatability for lactating goats. Many factors influence dry matter consumption, including the degree of feed palatability. Pazla et al. (2023) stated that palatability is the main factor explaining the difference in dry matter intake between feed and low-producing livestock. Based on recordings made during the investigation, it was discovered that goats' appetites are increased by the flavor and smell of banana peels, as evidenced by the high consumption of dry matter up to 15% replacement of field grass with banana peels.

Another factor that influences dry matter intake is the existence of limiting factors, lignin on digestibility values. In our study, the percentage of lignin content in the control diet (without banana peel) was higher than in the diet containing banana peel. High lignin levels will reduce digestibility because lignin is difficult to digest. This will affect feed consumption, namely a decrease in feed consumption, because the retention time of feed in the rumen is longer. Banana peels contain lignin (Anhwange 2008; Abou-Arab and Abu-Salem 2017), but the lignin content is lower than field grass. Providing a high proportion of banana peels in the ration means the lignin content is lower, so dry matter consumption increases. This is in accordance with the statement of Hermawan et al. (2017) that lignin is a limiting factor in digestibility values.

Bioavailability of Calcium in Lactating Etawa Crossbreed Goats Fed Banana Peel

Calcium plays an important role for all livestock, including lactating goats. If lactating goats did not receive necessary amount of Ca and P in their diet, they would draw from body stores of this element, without initially affecting milk yield or milk composition. If the calcium deficiency continued for weeks, the yield of milk decreased.

The bioavailability of Ca in lactating goats is an important factor that influences the health and milk production of these animals. The bioavailability of calcium in goats was determined by calculating the ratio between Ca absorbed and Ca consumed, as stated by Ningsih and Sanjaya (2022). When using banana peels up to 15% in the diet of lactating goats, the results of Ca bioavailability of lactating goat ranges from 53.84 to 57.64%, and these were not significantly different. This is partly caused by the ratio of Ca and P. In this study, the ratio of Ca and P in each treatment was almost the same (1.4:1). The Ca and P ratio obtained in this study already meets the standards for lactating goats, in accordance with Pugh's statement (2022) that the Ca and P ratio for lactating goats should be kept between 1:1 and 2:1.

The average value of calcium bioavailability for lactating goats found in this study was the same as stated by the NRC (2007) that the Ca absorption coefficient for lactating goats is 55%. Ca bioavailability is influenced by the source, and levels of Ca. Calcium is really needed by lactating goats for the Ca content in their milk and to avoid milk fever. Pugh (2022) states that adequate level of Ca calcium for lactating goats are necessary to prevent parturient paresis (milk fever). Because milk is high in Ca, rations for lactating goats need higher Ca level. In our study the level of Ca in diet was 0.64%, while the recommended dietary Ca level for lactating goats ranges from 0.3 to 0.8%. So Ca content of the ration prepared in this study has met the standard requirements for lactating goats (NRC 1981).

When using 15% banana peel in diet, the amount of Ca absorbed was 6.74g/d. There is no significant difference in the amount of Ca absorbed when using 0 up to 15% banana peel because the Ca content in the ration was almost the same, ranging from 0.62 to 0.64%. NRC (2007) state that the amount of Ca absorbed in lactating goats is determined by the amount of milk produced. In this study, the lactating Etawa crossbreed goats used produced milk ranging from 1.19 to 1.31 kg/d with an average amount of Ca absorbed of 6.48g/d. This value is in accordance with the standard for lactating goats according to the NRC (2007) that the Ca absorbed is 6.4g/d for goats that produce milk from 0.94 to 1.38g milk/d.

Calcium is absorbed in the form of Ca^{2+} ions (Diaz de Barboza et al. 2015; Shkembi and Huppertz 2022). Intestinal Ca^{2+} absorption is a crucial physiological process for maintaining bone mineralization and Ca^{2+} homeostasis (Diaz de Barboza et al. 2015). Calcium is absorbed in the mammalian small intestine by two general mechanisms: a transcellular active transport process, located largely in the duodenum and upper jejunum; and a paracellular, passive process that functions throughout the length of the intestine (Bronner 2003; Diaz de Barboza et al. 2015). The active Ca transport process occurs through 3 stages: the Ca^{2+} entry via epithelial Ca^{2+} channels through the brush border membranes (BBM) of enterocytes; Ca^{2+} transport by protein binding with a high affinity from the BBM to the basolateral membranes; ekstrusi Ca^{2+} into blood (Diaz de Barboza et al. 2015). Banana peels are low in calcium. Many factors that affect the mineral content of feed ingredients including protein and neutral detergent fiber (NDF), as stated by Fujihara et al. (2006) that the correlation coefficient of calcium mineral with protein is 0.63 and with NDF is 0.85.

Bioavailability of Phosphorus in Lactating Etawa Crossbreed Goats Fed Banana Peel

Phosphorus required for lactating goat is dependeds on P concentration in milk and amount of milk produce. Goats can maintain milk production on P deficient diets for several weeks by using P from body reserves, but during long periods of P deficiency, milk production was shown to decline by 60%. The Ca-P ratio should not drop below 1.2:1 in diets for goat (NRC 1981). This is because Ca and P interact through competition for uptake at the enterocyte. Therefore, their ratios in diets may influence their absorption and consequently availability (Kiarie and Nyachoti 2010). In this study, the Ca-P ratio was 1.4:1, so it was still within a safe standard. Absorption and the bioavailability value was not significantly different. The bioavailability value of P found was 49-50%. This value is close to the standard stated by NRC (1988) that the efficiency of P phosphorus absorption for lactating ruminants is 50%.

In fact, the P content of banana peels is much lower (0.08%) compared to P of field grass (0.24%). However, because the maximum use of banana peels in the ration in this study was 15%, the P content of the ration was not much different, ranging from 0.42 to 0.44%. This is one of the factors that determined the amount of P absorbed and its bioavailability. The absorbed P will be used by lactating goats to meet their need for P. NRC (1988) states that P phosphorus is a key mineral in energy metabolism, it is an essential component in the buffer system in blood and other body fluid, and it is important in almost every biochemical aspect of metabolism. Phosphorus is a factor in the metabolism of almost nutrients because of its role in enzyme activity.

Quality of Milk Components in Lactating Etawa Goats Fed Banana Peel

The primary substrates extracted from the blood by mammary gland in dairy goats are glucose, amino acids, acetate, butyrate and mineral. All of these substrates come from the process of digestion and absorption of feed substances in the rumen and post-rumen. The primary solid in cow's milk, lactose is a disaccharide sugar composed primarily of glucose and galactose molecules, accounting for about 40% of the total solids and 50% of the fat-free solids (Lemosquet et al. 2009; Costa et al. 2021). Blood glucose that is absorbed by the basal membrane of mammary epithelial cells is converted into lactose in the udder (Osorio et al. 2016).

In this study, lactose content increased from 3.27 to 4.00%, but this value was lower than Jamarun et al. (2020) by 4.45-5.83% of Etawa crossbred dairy goat fed combination of fermented oil palm fronds, *Titonia diversifolia* and elephant grass. Lactose influences the volume of milk produced by influencing the amount of water absorbed in the alveoli (Fox et al. 2015). Increasing lactose levels by increasing the use of banana peels to 15% has also been proven to increase goat's milk production, but statistically it was ~~is~~ not significantly different. The amount of milk produced based on 4% fat content was 1.20-1.31 kg. The milk production produced in this study was almost the same with the results stated by Pazla et al. (2022) who found that the milk production value of Etawa goats fed *Titonia diversifolia* and *Pennisetum purpureum* was 1.2 kg/day and Arief and Pazla (2023) who obtained milk production values of 1.01 to 1.66 kg/day in goats fed non-conventional forages and palm concentrate. The use of up to 15% banana peels in the ration can provide sufficient nutrients for milk production, so that milk production can be maintained. This milk yield was higher than even though banana peels contain anti nutrients in the form of tannins, which can bind protein, which will inhibit the use of protein and the availability of ammonia (NH_3) for rumen microbes. The use of 15% banana peels is still within a safe level. This can be seen from milk production which has not decreased.

One of the most important component of milk is milk fat. The average content of goat milk fat is 3.3% (Getaneh et al. 2016). The high fat content of milk produced in this study which ranged from 5.00-5.20%, was due to the amount of forage given being greater than concentrate. It is known that forage will produce more acetic acid which is a precursor to milk fat. According to Suwandyastuti and Rimbawanto (2015), the breakdown of complex carbohydrates in the rumen would result in ketogenic fermentation products, which will yield acetic and butyric acids.

Conclusion

The bioavailability of calcium and phosphorus in lactating goats can be maintained by feeding 15% banana peel in the ration with a value of 57.64 and 49.37% respectively with a goat's milk fat content of 5.21%; milk lactose 4.00% and milk protein 3.10%. This information is required in order to utilize banana peels as an energy source in ruminant diets without disrupting the process of mineral absorption and milk production. This research contributes to the provision of alternative feed for ruminant livestock, especially lactating dairy goats.

Author's Contribution

Fauzia Agustin designed the concept, searched for funding, conducted data analysis, drafted and reviewed the paper. Novirman Jamarun and Roni Pazla supervised the field and laboratory work, drafted the paper.

Hanannisa Suryadi conducted field and laboratory work as well as data tabulation, collected and prepared samples.

Competing Interest

The authors confirm that they don't have any conflict of interests.

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