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NUTRITIONAL AND ECONOMIC ANALYSIS OF COCOA AND COFFEE BEAN SKINS IN SILAGE PRODUCTION

Shirleen Samantha Halim[1], *Devi Maulida Rahmah*[2*]

[12]Department of Agricultural Industrial Technology, Faculty of Agricultural Industrial Technology, Padjadjaran University, Jl. Raya Bandung Sumedang KM.21, Hegarmanah, Jatinangor District, Sumedang Regency, West Java 45363
[*)]Email Correspondending author: devi.maulida.rahmah@unpad.ac.id

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ABSTRACT

Cocoa bean skin and coffee bean skin are biomass waste that is underutilized in Indonesia. Given the nutritional potential of cocoa and coffee bean skin biomass waste, processing it is considered to add potential value. The objective of this research is to investigate the potential of utilizing cocoa and coffee bean skin waste in silage production to address specific nutritional requirements. This will be accomplished through the analysis of nutritional characteristics via proximate analysis and the evaluation of economic value added (EVA). Characteristic analysis was carried out with predetermined parameters with raw materials from silage in the form of odot grass, corn husks and additional biomass in the form of cocoa and coffee bean skin waste with concentrations of 20%, 25% and 30% respectively. The results showed that cocoa bean skin silage generally has a higher fat and protein content than coffee bean skin silage. Meanwhile, coffee bean skin silage showed a higher crude fiber and carbohydrate content than cocoa bean skin silage. Economic Value Added (EVA) analysis also revealed that silage generated an added value of IDR 806,018 with a profitability value of 40%, indicating the economic potential in processing biomass waste into silage. Future research can optimize the formulation of biomass waste and explore various biomass sources to improve nutritional and economic benefits. Evaluation of these formulations on various livestock species can also provide valuable insights into their effectiveness in various types of livestock feed.

Keywords: *proximate analysis; cocoa bean skin; coffee bean skin; silage*

ABSTRAK

Kulit ari kakao dan kulit ari kopi merupakan limbah biomassa yang masih minim diolah di Indonesia. Dengan potensi nutrisi yang dimiliki limbah biomassa kulit ari kakao dan kopi, pengolahannya ini dinilai dapat menjadi potensi nilai tambah. Tujuan dari penelitian ini adalah untuk melihat potensi dari limbah kulit ari kakao dan kopi pada pembuatan silase untuk memenuhi kebutuhan nutrisi tertentu dengan melakukan analisis karakteristik nutrisi melalui analisis proksimat serta nilai tambah ekonomi/ *Economic Value Added* (EVA). Analisis karakteristik dilakukan dengan parameter yang sudah ditentukan dengan bahan baku dari silase berupa rumput odot, kelobot jagung dan tambahan biomassa berupa limbah kulit ari kakao dan kopi dengan konsentrasi masing-masing 20%, 25% dan 30%. Hasil penelitian menunjukkan bahwa silase kulit ari kakao umumnya memiliki kandungan lemak dan protein yang lebih tinggi dibandingkan silase kulit ari kopi. Sedangkan, silase kulit ari kopi menunjukkan kandungan serat kasar dan karbohidrat yang lebih tinggi dibandingkan silase kulit ari kakao. EVA juga mengungkapkan bahwa silase menghasilkan nilai tambah sebesar IDR 806.018 dengan nilai profitabilitas 40%, yang menunjukkan potensi ekonomi dalam pengolahan limbah biomassa menjadi silase. Penelitian mendatang dapat mengoptimalkan formulasi limbah biomassa serta mengeksplorasi berbagai sumber biomassa untuk meningkatkan manfaat nutrisi dan ekonomi. Evaluasi formulasi ini pada berbagai spesies ternak juga dapat memberikan wawasan berharga mengenai efektivitasnya dalam berbagai jenis pakan ternak.

Kata kunci: analisis proksimat; kulit ari kakao; kulit ari kopi; silase.

INTRODUCTION

Indonesia's diverse natural resources make it a country with significant biomass potential. However, the knowledge and technology used to process biomass into value-added products are considered still limited. Efforts to educate the public about the potential use of biomass and its sustainability are relatively rare. As a result, biomass waste from processing often goes unmanaged. Innovations in biomass waste processing could really help lessen environmental harm. Biomass has the potential as a renewable energy source related to diversification of energy supply, environmental benefits, and sustainability (Santosa et al., 2023).

The negative impacts on the environment that can be caused by biomass waste (both solid and liquid waste) such as water pollution, air pollution and soil contamination. One example of biomass waste produced in Indonesia is biomass waste from cocoa and coffee. Cocoa is one of the commodities whose production increases every year. With the increase in production from cocoa itself, this is directly proportional to the waste from cocoa processing itself. Cocoa production itself in Indonesia in 2022 reached 688.211 thousand tons (Badan Pusat Statistik Indonesia, 2022). The main waste produced from cocoa processing is are the cocoa pod husks and the cocoa bean shells. In the commercialization process, 90% of the total weight of the cocoa fruit is discarded as waste or by-products and only about 10% is used (Poveda et al., 2020).

On the other hand, the coffee processing industry also generates a lot of biomass waste that can be reprocessed. In this sector, the main by-product is coffee skin, which makes up 43.2% of the weight of the coffee fruit, while the actual coffee beans account for only 38.9% of the weight (Silva et al., 2023).

In the processing of coffee beans, it also produces waste in the form of coffee skin which represents 4.2% (w/w) of the total weight of the beans. Approximately 50-60% of the waste generated in the coffee processing industry consists of coffee husks, indicating that the amount of waste produced exceeds the quantity of the final product (Rusdianto et al., 2021). Coffee skin is a by-product of the roasting process. Processing 120 tons of roasted coffee yields 1 ton of coffee skin as a by-product (Martuscelli et al., 2021). Coffee skin itself has high soluble dietary fibers (86% of total dietary fibers) and high antioxidant activity (Prabha et al., 2022). Due to the limited knowledge of farmers in utilizing biomass waste, farmers often dispose of it by cutting it into pieces or mixing it with soil as fertilizer. Some do not process it at all by letting it decompose in the soil. This causes soil pollution, unpleasant odors, and greenhouse gas emissions which are considered detrimental to the environment (Ramos et al., 2023).

Despite having good nutritional content, cocoa bean skin and coffee bean skin cannot be given directly to animals because of their high fiber content and low digestibility. Therefore, farmers usually carry out an ensiling process to reduce the high fiber content , making it more suitable for animal consumption. The ensiling process involves fermenting cocoa bean skin or coffee bean skin with lactic acid bacteria, which reduces the pH and preserves the ingredients. Thus, the feed becomes more digestible and balanced for animals, especially ruminants (Poveda et al., 2020). This ensiling process can also be carried out in the silage making process. Silage is a method for preserving fresh green fodder, without using oxygen and with the addition of acid. By providing animal feed that is always available and of good quality, it can be one of the first steps to achieving optimal productivity (Kurnianingtyas, 2012).

Making silage for animal feed can help address challenges such as limited feed sources, the distance between feed sources and farms, and low feed quality. Additionally, it can mitigate issues related to seasonal or limited feed availability throughout the year, as well as the flammability of most animal feed. In addition, to ensure that feed needs are met, biomass is added to the silage. Research has demonstrated the addition of various biomass types in silage production: rice straw and forage silage (Kolo et al., 2024), banana peel silage (Deviany et al., 2024), elephant grass mixed with coffee skin silage (de Figueiredo et al., 2022), sorghum, Tamani Guinea Grass and *Stylosanthes* silage (Prado et al., 2023), onggok, which is a by-product of making tapioca flour from cassava (Anissa et al., 2024), *Pennisetum purpureum* silage with the addition *Indigofera zollingeriana* leaf silage (Nurcahyati et al., 2024), and coffee grounds silage (Batbekh et al., 2023).

In this study, the silage making process involved the addition of biomass waste in the form of cocoa and coffee bean skin waste, each with different concentrations, the nutrients of which were analyzed using proximate analysis and Economic Value Added (EVA) analysis to evaluate the economic value of the silage. EVA is a technique employed to measure the value created by a product.

This added value is calculated from the investment made, namely by subtracting capital costs from operational costs (Tortella & Brusco, 2003). This study aims to determine the type of biomass waste that is more suitable to meet certain nutritional needs in silage. The findings in this study are expected to help farmers in making the right decisions about the most effective and efficient use of biomass waste according to livestock feed needs.

MATERIALS AND METHODS

Tools and Materials

In the process of making silage, the main raw materials used are odot grass and corn husks, while additional materials include EM4, biomass waste in the form of cocoa bean skin, and coffee bean skin. The tools used for making silage involve a chopper, knife, oven, measuring cup, analytical balance, and 5 milliliter syringe. All materials, including the cocoa bean skin and coffee bean skin, were obtained from local farmers in the province of West Java, Indonesia.

Silage Making Process

The silage making process used in this study was carried out in several steps. First, fresh odot grass was wilted for at least 24 h to reduce its moisture content, while the corn husks underwent a washing and drying process. After that, the odot grass and corn husks were chopped into a size of about 2 cm. Furthermore, the preparation involved by making EM4 solution by mixing 1 ml of EM4 with 1000 ml of water. In the main silage mixture, 170 grams of odot grass and 50 grams of chopped corn husks were added. Then, 5 ml of EM4 solution was added, along with biomass waste in the form of coffee bean skin and cocoa bean skin at predetermined percentages (20%, 25%, and 30%).

Table 1. Silage Treatment

Silage	Biomass Waste				Corn Husks	Odot Grass	EM 4 & Water Solution (1:1000)
	Cocoa Bean Skin		Coffee Bean Skin				
	%	g	%	g	g	g	ml
A1	20	44	0	0			
A2	25	55	0	0			
A3	30	66	0	0	50	170	5
B1	0	0	20	44			
B2	0	0	25	55			
B3	0	0	30	66			

Ensure that the silage ingredients are placed in an oxygen-free environment within the container, as the presence of oxygen can interfere with the fermentation process. The fermentation treatment of livestock feed with the addition of coffee husks is considered to enhance the nutritional value of the coffee husks (Rusdianto, Wiyono, Wahyuni, et al., 2021). The fermentation process is carried out for a full month, after which, the silage is dried in an oven at a temperature of 100 – 150°C for ± 45 minutes - 1 h. Then, the dried silage is ground into powder using a grinder and analyzed proximately to assess its nutritional content.

Proximate Analysis Parameters

The parameters used in analyzing nutritional characteristics through proximate analysis are fat content, water content, ash content, crude fiber, protein content and carbohydrates contained in the silage. Fat content analysis is carried out to determine its nutritional value, as fat functions as a source of energy. Water content analysis is conducted to assess the freshness and storage period of the material, as water content can affect the overall presentation of nutrients. Ash, a residue from combustion, is analyzed to determine mineral content and the types of materials used in the manufacturing process (Mukti, 2021).

Crude fiber analysis measures the remaining carbohydrates after digestion with sulfuric acid and sodium hydroxide solutions. The use of EM4 in silage can increase crude fiber content due to the microorganisms contributing crude fiber through their cell walls (Rusdianto, Wiyono, Putri, et al., 2021). Higher crude fiber content leads to a higher digestion rate and shorter digestion time, potentially reducing protein digestibility (Prawitasari et al., 2012).

Protein content analysis determines protein levels, which are crucial for the growth and health of livestock, as protein is an essential nutrient in animal feed. Then carbohydrate analysis is also carried out in determining the nutritional characteristics of silage. Carbohydrates themselves are useful for converting energy and helping the metabolic process so that the analysis of carbohydrate levels can also affect the quality and nutrition of a material (Mukti, 2021). This stage ensures the use of biomass waste in effective and efficient silage production.

Economic Value Added Analysis

Economic Value Added analysis in this silage is calculated using the Economic Value Added (EVA) approach. The added value itself is the difference between sales and costs incurred to produce (raw materials and purchasing supporting materials

Table 2. EVA Calculation

Net Sales	xxx	
Cost of Goods Sold (COGS)	xxx	-
Gross Profit	xxx	
Operating Costs	xxx	-
Earnings before Interest and Taxes (EBIT)	xxx	
Taxes	xxx	-
Net Operating Profit After Tax (NOPAT)	xxx	
Cost of Capital	xxx	-
Economic Value Added (EVA)	xxx	

The performance measurement of EVA involves using 100 kg of silage as the standard criterion. This approach is based on the methodologies (Risal & Djadid, 2016).

$$\text{Profitability}=\frac{\text{EVA}}{\text{Net Sales}}\ .\ 100\%.........[1]$$

RESULTS AND DISCUSSION

This study conducted a comparative analysis of nutrients in silage with the addition of coffee bean skin and cocoa bean skin biomass waste, using proximate analysis. The measurement parameters used in this study included fat content, water content, ash content, crude fiber, and protein content. All samples were prepared in powder form for the proximate analysis. A total of six samples were analyzed, consisting of silage samples with cocoa bean skin (Sample A) and coffee bean skin (Sample B).

Sample A was made with three different concentrations of cocoa bean skin: 20% (A1), 25% (A2), and 30% (A3). Similarly, Sample B was prepared with three different concentrations of coffee bean skin: 20% (B1), 25% (B2), and 30% (B3). The following are the results of the proximate test analysis for the two types of samples, Sample A and Sample B.

Several parameters are utilized to analyze the nutritional characteristics of silage.

Table 3. Proximate Analysis Results of Silage Samples at Various Concentrations

NO	Sample Code	Parameter (Unit %)					
		Fat Content	Water Content	Ash Content	Crude Fiber	Protein Content	Carbohydrate
Cocoa Bean Skin Silage							
1	A1 (20 %)	5.13	6.56	11.49	23.36	15.38	61.44
2	A2 (25 %)	3.68	7.48	11.24	20.43	15.93	61.67
3	A3 (30 %)	4.29	6.98	11.23	20.03	16.14	61.36
Coffee Bean Skin Silage							
1	B1 (20 %)	1.61	7.33	13.53	41.38	7.72	69.81
2	B2 (25 %)	1.62	6.62	11.65	46.41	7.61	72.5
3	B3 (30 %)	1.18	7.87	12.54	46.77	7.11	70.67

The first parameter examined is fat content, with silage B3 showing the lowest fat content at 1.18%, and silage A1 the highest at 5.13%. These differences result from the distinct properties of the raw materials used in silage preparation. Cocoa bean skin, which is used in silage A1, naturally contains more fat (1.50 to 8.49%) (Poveda et al., 2020) compared to coffee bean skin (1.56 to 3.28%) (Narita et al.,2014), which explains the lower fat content in silage B3. Moreover, differences in ingredient quality, processing methods, and measurement techniques can lead to these variations. Although some samples have a higher biomass concentration, other factors such as ingredient quality and processing variability may cause certain samples to exhibit higher fat content. The fat content in this livestock feed is considered to affect the condition of the livestock, such as their adaptation to the environment. This is because fat itself functions as an energy supplier for the body (Yuvita et al., 2020).

Generally, the crude fat content in ruminant livestock feed is usually below 5% (Yuvita et al., 2020). The average fat content in group A silage is 4.37%, while the fat content in group B silage is 1.47%. Referring to generally fat content in livestock feed, which is below 5%, both groups of silage meet this standard. However, it should be noted that the type and concentration of biomass need to be considered. It can be seen that silage A1 with a fat content of 5.13% does not meet the standard fat content in livestock feed, but the fat content in silage A2 and A3 falls within the standard fat content for livestock feed.

The higher fat content in the A1 sample, despite having a lower concentration of cocoa bean skin (20%) compared to A2 and A3 (25% and 30%, respectively), can be due to a few factors. Lower microbial activity in A1 may result in less breakdown of fats, retaining more lipids in the silage. Cocoa bean skin has varying fat content (1.50% to 8.49%) (Poveda et al., 2020), and even a lower concentration can yield high fat content if fermentation conditions favor fat retention. Variability in sampling and measurement can also cause differences. These factors suggest that both the concentration of cocoa bean skin and other variables like microbial activity and measurement can influence the fat content.

As for the moisture content parameter, it was found that the silage with the lowest moisture content was silage A1 (6.56%) and the highest was silage B3 (7.87%). The moisture content in silage is considered to affect the quality of the silage and its shelf life. Generally, the moisture content in silage ranges from 60-65% (Denaneer et al., 2021). The moisture content in the silage in this study was considered very low. This was due to the prolonged drying time of the silage during the pulverization process or the drying temperature being too high (Borreani et al., 2018). Referring to the standard moisture content in silage, which ranges from 60-65%, both groups of silage do not meet this standard.

Then, for the ash content parameter, it was found that several silages had similar ash content, but the lowest ash content was found in silage A3 (11.23%) and the highest in silage B1 (13.53%). The ash content in silage generally comes from nutrients and minerals in the raw materials used in silage production. High ash content in silage indicates contamination of the silage raw materials by other substances that cannot be digested by livestock. This shows that low ash content in silage indicates that the silage has good

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physical and nutritional quality (Kuncoro et al., 2015). The ash content in silage generally ranges from 6-8% (Baharuddin, 2022). Referring to (Baharuddin, 2022), the ash content in both groups of silage does not meet this standard.

The next parameter is crude fiber content. In this study, the crude fiber content in the silage group A was lower compared to the silage in group B, with the lowest crude fiber content in silage A3 (20.03%) and the highest in silage B3 (46.77%). Crude fiber in silage is considered to affect the digestibility of feed in ruminants. Therefore, the higher the crude fiber content, the lower the feed digestibility (Baharuddin, 2022). Additionally, the fermentation process is also considered to reduce crude fiber content (Baharuddin, 2022). In this study, the crude fiber content test results in the silage group A ranged from 21.27% and in the silage group B ranged from 44.85%. The need for crude fiber in silage depends on the type of livestock and the raw materials used in the silage production process.

The next parameter is protein content, where the protein content in the silage group A was higher compared to the silage in group B, with the lowest protein content in silage B3 (7.11%) and the highest in silage A3 (16.14%). Protein is regarded as a crucial nutrient required by livestock. For example, protein content in livestock feed such as sheep or beef cattle, ranges from 10-14% (Wahlberg, 2009).

The higher protein content in silage group A can be attributed to the natural composition of cocoa bean skin, which has a higher protein content (10.30–27.40%) (Poveda et al., 2020) compared to coffee bean skin (16–19%) (Narita et al.,2014). Additionally, the processing and fermentation conditions can influence the protein retention in silage. Effective ensiling conditions can preserve protein content by minimizing protein degradation and enhancing protein availability through microbial action.

This preservation effect is reflected in the higher protein content observed in A3 (16.14%), which surpasses the typical range for livestock feed. Conversely, the lower protein content in silage group B, particularly B3 (7.11%), may result from the lower inherent protein content of coffee bean skin and potential losses during processing. These variations highlight the importance of considering raw material composition and processing methods in determining the nutritional quality of silage.

In terms of carbohydrate content in silage for each group, the carbohydrate content in group A had values that were not too far apart, and the carbohydrate content in silage group A was lower compared to silage in group B. The lowest carbohydrate content was found in silage A3 (61.36%) and the

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highest in silage B2 (72.5%). Carbohydrates are often referred to as an energy source needed by livestock.

The optimal carbohydrate content depends on the type of livestock feed and the variation or formulation of raw materials used in the silage production process. The carbohydrate content in silage made from elephant grass with the addition of cassava tape juice is 40.2% (Sulistyo et al., 2020). In this study, the average carbohydrate content in silage group A was 61.49% and for silage in group B was 71.66%.

Higher carbohydrate content in coffee bean skin silage, due to higher carbohydrate content in the coffee bean skin which ranges from 34.6–80.5% (Narita & Inouye, 2014) than cocoa bean skin carbohydrate content typically ranging from 34.27% to 61.36%, depending on the processing method and variety (Poveda et al., 2020). It should also be noted that the carbohydrate needs in silage depend on the type of silage raw materials and the type of livestock feed.

In general, cocoa bean skin silage (A1, A2, A3) tends to have higher fat and protein content compared to coffee bean skin silage (B1, B2, B3). Although coffee bean skin silage has lower fat and protein content, this coffee bean skin silage shows higher levels of crude fiber and carbohydrates.

Table 4. EVA Performance Measurement in Silage Products

Goat Feed 100 kg							
Silage COGS				Animal Feed Grass COGS			
Raw Material (RM)				Raw Material (RM)			
Type	Amount (g)	Price		Type	Amount (g)	Price	
Biomass Waste	22680	Rp	102.062	Odot Grass	100000	Rp	1,500.000
EM 4	1718	Rp	0.920				
Corn Husk	17182	Rp	80.000				
Odot Grass	58419	Rp	876.000				
Auxiliary Materials (AM)				Auxiliary Materials (AM)			
Shipping Service		Rp	-	Shipping Service		Rp	-
Composter Jar 120 L		Rp	135.000			Rp	-
Total RM & AM		Rp	1,193.982	Total RM & AM		Rp	1,500.000
Labor Cost		Rp	-	Labor Cost		Rp	-
Fixed Overhead Cost		Rp	-	Fixed Overhead Cost		Rp	-
Variable Cost		Rp	-	Variable Cost		Rp	-
Total COGS		Rp	1,193.982	Total COGS		Rp	1,500.000

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Table 5. EVA Silage Measurement

EVA Measurement (Sales of 100 kg Silase)		
1 kg silage is priced at	Rp 20.000	
Net Sales	Rp2,000.000	
COGS	Rp1,193.982	
Gross Profit	Rp 806.018	
Operating Costs	Rp -	
Operating Profit Before Tax	Rp 806.018	
Tax	Rp -	-
Net Operating Profit After Tax	Rp 806.018	
Capital Costs	Rp -	-
EVA (Economic Value Added)	Rp 806.018	
		0
Profitability		0.403009072
		40%

From the calculation of EVA and profitability percentage in Table 5. and Table 6., it was found that the processing of biomass waste into silage produced EVA of Rp806,018. Meanwhile, the profitability percentage generated from the calculation of silage was 40%. This means that for every Rp1,000 from the sale of this silage, it can produce economic added value (EVA) of Rp400.

CONCLUSIONS

Proximate analysis was used on silage with the addition of biomass waste in the form of coffee bean skins and cocoa bean skins to determine the type of biomass waste that is more suitable or the formulation used to meet specific nutritional needs in silage. There are two types of silage groups: group B (coffee bean skins) and group A (cocoa bean skins) at varying concentrations (20%, 25%, and 30%). This study shows that silage with the addition of cocoa bean skins tends to have higher fat and protein content, when compared to coffee bean skin silage which has higher crude fiber and carbohydrate content. The Economic Added Value (EVA) analysis in this study also showed an added value of IDR 806,018 with a profitability of 40%. This shows the economic benefits of using biomass waste in silage processing.

RECOMMENDATIONS

Future research is recommended to focus on optimizing the formulation of biomass waste and explore various types of biomass sources to maximize nutritional and economic benefits.

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