Research Article

Sheep Performance on Valuable Silage and Wafer from Agricultural Waste

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Abstract | Increasing the availability of feed ingredients is important for the sustainability of livestock rearing. The use of agricultural waste as animal feed will not only improve food security but also contributes to the alleviation of environmental problems associated with waste management. This study aims to evaluate the growth performance of local sheep fed with agricultural waste in the form of silage and wafers. The study consisted of five treatments and four groups using 20 local male sheep. The results showed that feeding local sheep with agricultural waste in the form of silage and wafers had a significant ($P < 0.05$) effect on the dry matter, crude protein, and crude fat intake and was able to increase final body weights and feed efficiency compared to sheep fed with conventional feed. Processing of agricultural waste into silage and wafers can improve the performance of local sheep so that agricultural waste has great potential to be used as animal feed.

Keywords | Agricultural by-product, Bean sprouts waste, Cassava leaves, *Leucaena leucocephala* L. leaves; Productivity

Received | October 06, 2022; **Accepted** | October 25, 2022; **Published** | February 13, 2023
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Citation | Retnani Y, Sukria HA, Wijayanti I, Diapari D, Erlangga MD, Ibsyah MF, Taryati, Barkah NN, Qomariyah N (2023). Sheep performance on valuable silage and wafer from agricultural waste. Adv. Anim. Vet. Sci. 11(3): 417-423.
DOI | http://dx.doi.org/10.17582/journal.aavs/2023/11.3.417.423
ISSN (Online) | 2307-8316

INTRODUCTION

The increase in consumption of animal products in the future will result in a large demand for feed. Meeting the demand for feed sustainably will be a challenge against the backdrop of climate change, food-fuel-feed competition, land degradation, water shortages, and loss of biodiversity (Pulina et al., 2017). Two obvious options for increasing the availability of feed ingredients are, firstly, efficient use of available feed resources, and secondly, expansion of the feed resource base, primarily focusing on feed resources that do not compete with human food. The use of non-food parts of agricultural products as animal feed will not only improve food security but also contribute to alleviating environmental problems associated with waste management. Utilization of agricultural wastes as animal feed such as waste of old leaves, such as *Leucaena leucocephala* L. leaves, *Calliandra calothyrsus* leaves, *Moringa*, *Gliricidia sepium* leaves, sugarcane waste, market vegetable waste, and black seed waste has not been used optimally. Agricultural waste can be a source of energy for ruminants, a provider of protein and active compounds that can increase immunity and livestock productivity if processed in the right way. One of the feed processing technologies that have been developed is to make the feed into wafer form. Until now, agricultural waste has not been used optimally, so it is necessary to review its benefits as animal feed.

Agricultural waste can be divided into two main groups, namely post-harvest agricultural waste and agricultural waste from the processing industry of agricultural products, post-harvest agricultural waste is the part of the plant on the ground or its shoots that remains after harvesting or the main product is taken, while what is meant by agricultural waste is residual agricultural waste. The agricultural product processing industry is the residue from the processing of various main agricultural products. According to Acker (1971), agricultural or industrial wastes processing agricultural products can be grouped based on protein contents into 3 qualities, less than 10%, 10-18%, and more than 18% of dry matter. Feed raw materials derived from agricultural wastes contain chemical compositions that are indispensable for livestock. On the other hand, delays in harvesting lead to high lignin, reduced fiber digestibility, and palatability (Hancock and Collins 2006). Until now, agricultural wastes had not been widely used as animal feed. The application of appropriate feed processing technology can optimize the quality of the nutrients contained in agricultural wastes. One of the feed processing technologies that have been developed is the processing of feed into silage and wafers. Wafer form feed has been researched by Retnani et al. (2014a); Retnani et al. (2014b); while silage processing has also been widely researched, one of which is by Sun et al. (2021);(Yang et al. 2016). The purpose of making silage is to produce a solid feed with high healing of dry matter, strength, and incredibly digestible nutrients as compared with the sparkling crop. Microbial fermentation inside the silo produces an array of end products and may exchange many nutritive factors of a forage (Kung Jr et al., 2018). Feed in the form of by-product feed-based-silage (BF-silage) given to steers produces fiber-rich feed for growth or fattening and increases the intake of DM and neutral detergent fiber (NDF) (Kim et al., 2015a, 2013, 2015b); by-product feed-based-silage (BF-silage) results in higher energy and protein utilization values, and lower fiber digestion in sheep (Seok et al., 2016) and reduce the use of feed supplements (Hendricks et al., 2021).

However, the effects of agricultural waste in the form of silage and wafers on sheep remain unclear. Thus, the objective of this study was to evaluate the growth performance of local sheep fed with agricultural waste in the form of silage and wafers.

MATERIALS AND METHODS

Ethical approval

The cannulation surgery of animals was carried out by a licensed veterinarian and followed the protocol for handling and care of animals, according to the IPB University Animal Ethics Committee.

Silage and wafer processing

Forage materials (*Leucaena leucocephala* L leaves, *Cassava* leaves, and bean sprouts waste) are first dried in the sun until the moisture content is below 14%. After drying, the forage material was mixed with other ingredients according to the formulation in Table 1 using a mixer machine WLH200 for 100 kg capacity. After homogeneously mixed, a part of the mixture continued to be made into silage and the other part continued to be made into wafers. Complete feed silage treatment refers to Kondo et al. (2016). The process of making silage was carried out by adding 5% lactic acid bacteria in the form of EM4 to the feed mixture. This mixture was put into a plastic bag, then the plastic was sealed so that no air enters and the fermentation process occurs optimally. The ensilation process was carried out for 21 days and silage was served to sheep. The process of making was carried out by entering the feed mixture into the wafer. The wafer machine used in this study was homemade by pressing and heating techniques at 80°C for 10 min and the size was 5 × 5 × 3 cm. Feed was packed in a sack and stored in a clean warehouse. The nutritive value of silage and wafer is shown in Table 1.

Animals and experimental design

Twenty Indonesian local male sheep of five months and 12.57±1.52 kg were divided into four groups of one sheep per replicate. The grouped sheep were randomly assigned to one of the five experimental diets that included P0: 70% forage + 30% concentrate, P1: *Leucaena leucocephala* L leaves and bean sprouts silage, P2: *Leucaena leucocephala* L leaves and bean sprouts wafers, P3: *Leucaena leucocephala* L and *Cassava* leave silage, P4: *Leucaena leucocephala* L and *Cassava* leaves wafer. The diets were formulated with 20 kg and daily weight gains of up to 150 g /head/day to meet the nutrient requirement of sheep according to Kearl (1982); the ingredients and chemical composition of the experimental diets are shown in Table 1. This study included a 14-day prefeeding period and a 3-day data collection period. Feed remaining after one day was weighed every next morning. The sheep were housed individually in pens, with feed offered twice in equal amounts at 08:00 and 17:00, with *ad-libitum* access to fresh water throughout the experimental period. Before the adaptation period, 2 mL Albendazole was orally administered to each sheep to minimize internal parasitism.

The macroclimatic conditions at the experimental site were humid tropical, with an average temperature and relative humidity (RH) in the morning, afternoon, and evening during the study were 18.84°C and 88.78%, 24.97°C and 79.06%, and 21.19°C and 87.38%, respectively.

Table 1: Feed ingredients and chemical composition of agricultural waste silage and wafer (%)

Components	P0	P1	P2	P3	P4
Leucaena leucocephala leaves	0	25	25	20	20
Cassava leaves	0	0	0	30	30
Bean sprouts waste	0	25	25	0	0
Pollard	0	10	10	10	10
Palm kernel meal	0	26	26	26	26
Molasses	0	9	9	9	9
Calcium carbonate ($CaCO_3$)	0	1	1	1	1
Urea	0	1	1	1	1
Premix	0	1	1	1	1
Dicalcium phospate	0	1	1	1	1
Salt	0	1	1	1	1
Nutrient content					
Dry matter	42.0	76.1	91.6	77.1	90.6
Ash	11.1	10.6	7.55	10.0	9.27
Crude protein	12.0	23.0	20.6	23.7	24.0
Ether extract	1.86	1.94	2.95	2.20	3.88
Crude fiber	19.9	17.3	18.0	14.6	13.8
Nitrogen free extract	55.1	47.2	50.9	49.6	49.0

P0: forage, P1: Leucaena leucocephala leaves and bean sprouts silage, P2: Leucaena leucocephala leaves and bean sprouts wafers, P3: Leucaena leucocephala and cassava leaves silage, P4: Leucaena leucocephala and cassava leaves wafer.

Sampling and measurements

The physical test of silage feed includes moisture contents, water activity, and pH. The physical test of the wafer included moisture contents, water activity, bulk density, specific density, and wafer durability. Evaluation of local sheep growth performance was carried out through the nutrient intake, average daily gains, the efficiency of ration usage, and income over feed cost (IOFC). Nutrient intake was calculated based on the feed intakes with nutrient contents in them. The calculated nutrient intake is dry matter intake (DMI), crude protein (CP), ether extract (EE), crude fiber (CF), and nitrogen-free extract (NFE). The average daily gain (ADG) of sheep was performed every two weeks to determine the weight gains. Efficiency value can be obtained from feed intakes and weight gains during maintenance. The IOFC value was calculated to know the profit gained after the maintenance process. The IOFC value was based on the purchase and selling price of sheep and feeding costs during the research period. The purchase and selling price of sheep was obtained from the price in effect in June 2022 in the Bogor market, West Java, Indonesia.

IOFC = Selling price of sheep - (purchase price of sheep + feed cost during research period)

Statistical analysis

Statistical analysis of the data was conducted using the one-way ANOVA procedure in SPSS v20.0. For the analysis, experimental animals were included as a random effect, and treatment was included as a fixed effect. Duncan's test was used to determine differences between means. Least square means were expressed in tables, and significance was declared for P-values < 0.05 and trends at $0.05 < P < 0.10$.

RESULTS AND DISCUSSION

In agricultural waste silage, the water contents showed a range of 22.93 to 24.39% (Table 2). Based on research carried out by Situmorang et al. (2021), silage using additional concentrate had a high dry matter and low water contents. However, it can still be fermented with water contents ranging from 20 to 25%. Verma et al. (1996) found that water contents of about 8-12% are desired to get the optimal limit. The value of water activity in this study is in the range of 0.76 to 0.88. Wang et al. (2012) revealed that water activity of up to 0.8 – 0.9 is a requirement for yeast to survive and grow, so this indicated that there were microorganisms from silage that help the ensilage process has developed. The pH level for silage containing *Leucaena leucocephala* L leaves and bean sprout waste in this study was 5. Good silage has a pH between 3.80-4.20 (Ratnakomala et al., 2006). A high pH value (6.4-7.0) is also produced in the manufacture of silage from red algae (Gallagher et al. 2021). Silage pH silage can be grouped as very good, good, medium, and bad with a pH range of 3.20-4.20 each; 4,20-4,50; 4.50-4.80, and >4.80 (McCullough 1977). The high

Table 2: Physical quality of agricultural waste silage

Parameters	Leucaena leucocephala leaves and Bean Sprouts waste silage	Leucaena leucocephala and Cassava leaves silage	Reference
Moisture content (%)	24.39±1.04	22.93±0.40	20-25
Water activity	0.88±0.00183	0.76±0.0158	0.8-0.9
pH	5±0.00	5.00±0.00	<5

Table 3: Physical quality of agricultural waste wafer

Parameters	Leucaena leucocephala leaves and Bean Sprouts wafer	Leucaena leucocephala and Cassava leaves wafer	Reference
Moisture content (%)	8.35±0.321	9.39±0.0769	<9
Water activity	0.57±0.00624	0.61±0.0183	<0.6
Bulk density (g/cm^3)	0.49±0.081	0.666±0.910	0.48-0.89
Specific density (g/cm^3)	1.29±0.152	1.28±0.117	>1
Durability (%)	96.73±1.428	95.92±1.714	97-99

Table 4: Effects of feeding agricultural waste in the form of silage and wafers on nutrients intake of local sheep

Parameters	P0	P1	P2	P3	P4
Nutrient intake					
Dry matter (g/head/day)	408.03±20.70a	649.19±41.78b	537.92±14.42ab	1013.70±97.92c	583.11±19.74b
Crude protein (g/head/day)	48.87±4.62a	155.75±6.90b	123.94±6.09b	240.50±22.08c	131.20±3.95b
Ether extract (g/head/day)	7.49±0.62a	20.87±1.53bc	18.86±1.02b	22.32±2.16bc	22.74±0.67c
Crude fiber (g/head/day)	80.32±6.94a	125,72±11.60b	98.34±2.98a	148.14±14.31c	79.66±2.33a

P0: forage, P1: Leucaena leucocephala leaves and bean sprouts silage, P2: Leucaena leucocephala leaves and bean sprouts wafers, P3: Leucaena leucocephala and cassava leaves silage, P4: Leucaena leucocephala and cassava leaves wafer, SE: standard error. Different letters in the same row showed significant differences (P<0.05)

Table 5: Effects of feeding agricultural waste in the form of silage and wafers on growth performance of local sheep

Parameters	P0	P1	P2	P3	P4
Initial body weight (kg)	12.08±1.63	12.55±0.91	13.09±2.09	12.56±1.59	12.43±0.94
Final body weight (kg)	12.83±1.28a	16.15±2.37b	16.05±1.72b	16.24±2.44b	18.88±4.49b
Total body weight gain (kg)	0.46±0.86	3.60±2.01	2.96±0.44	4.11±0.64	4.11±3.26
Average daily weight gain (g/head/ day)	13.69±24.52	103.43±57.26	85.68±13.67	117.29±18.33	117.50±93.22
Feed efficiency (%)	3.13±5.82a	9.20±4.60ab	12.44±2.28b	11.60±1.74b	15.97±7.84b

P0: forage, P1: Leucaena leucocephala leaves and bean sprouts silage, P2: Leucaena leucocephala leaves and bean sprouts wafers, P3: Leucaena leucocephala and cassava leaves silage, P4: Leucaena leucocephala and cassava leaves wafer, SE: standard error. Different letters in the same row showed significant differences (P<0.05)

pH value is thought to be caused by the addition of palm kernel meal which also causes protein addition to silage. High protein will result in protein damage or proteolysis. Cardio spoilage initiated by using lactate-assimilating yeasts can also be chargeable for better than ordinary pH values in silages (McDonald et al., 1991). According to Ohshima and McDonald (1978), high proteolysis can increase the *buffer* capacity of the silage and this will further inhibit the decrease in the pH of the silage. Silage processing can increase the nutrient contents because there is an increase in dry matter due to the process of reducing water contents. The environmental temperature also made a great influence on Lactic Acid Bacteria (LAB) and dry matter loss (Wang et al., 2019).

The water activity of the research agricultural waste wafer was 0.57-0.61 (Table 3). Microorganisms cannot multiply and survive at a water activity level below 0.6 so wafers with a water activity level had to be below this value. The wafer moisture contents in this study were 8.35-9.39 %. This is a good approximation for the water content of wafers was approximately 12%-14% (Trisyulianti et al., 2003). The value of the specific density of the wafers in this study was 1.28-1.29 g/cm^3. The density of the wafer was influenced by the density of the raw material and the pressure applied during the process. High-density wafers will have a thick and hard texture, but low-density wafers will have a thinner, softer texture, and more cavities. A complete wafer ratio that has a high density will have a thick and hard texture (Retnani et al., 2017). While the wafers in this study have an impact resistance value of 96.73-95.92 % so they are still categorized as wafers with good durability. Wafers have a high feeding efficiency because there is a heating process so that there is particle compaction which causes the wafer to have high nutritional value.

Feed intake is related to the quantity of feed consumed by the animal in a certain period. Intake is one of the important factors that can affect livestock performance. According to McDonald et al. (2012), feed intake is influenced by feed, livestock, and the environment. Feed factors are influenced by nutrient content and its ability to meet basic needs, growth, and reproduction (Teferedegne, 2000), physical and chemical characteristics (Forbes, 2007), feed form (McDonald et al., 2012), as well as processing processes and fermentation rhythms in the rumen (Jayanegara et al., 2017). The addition of silage additives in the form of molasses can improve feed palatability. According to Sudarman et al. (2016), the quality of silage with molasses additives as large as 5 - 10% produces better silage quality and has a significant effect ($P < 0.05$) on fermentability and digestibility *in-vitro*.

Based on the statistical test results of dry matter intake in Table 4, the values were significantly different ($P < 0.05$). Dry matter intake in this study was between 3.14 - 4.02% of the sheep's body weight. Referring to the (NRC 2007), the need for feed for sheep weighing 10-20 kg with a daily body weight gain of 100-200 g/d/h is 3-5%. The increase in dry matter intake is attributed to the exposure of animals to transportation stress. The increase in dry matter intake is also influenced by the high dry matter contents in the feed, the research feed has a high dry matter content due to processing that reduces the water contents of the feed. The best nutrient intake was obtained by silage feed because of its palatability and increased intake.

Crude protein intake in Table 4 recorded significantly different values ($P < 0.05$). Crude protein intake in this study was following the needs of NRC (2007) which required 127-167 g/head/day for 10-20 kg sheep with an average daily weight gain of 100-200 g/head/day. Crude fiber intake in sheep after being tested showed significantly different results ($P < 0.05$) between silage, wafer feed, and control. the differences were attributed to feeding processing that can reduce crude fiber contents in the feed, especially feed processing through heating. The cause of the decrease in crude fiber in the material is due to the decomposition in the cell wall due to the heating process.

The results showed a very significant effect ($P < 0.05$) between the feed given to average daily weight gains. Post-transport body weight recovery can be seen from the increase or return of sheep body weight during rearing post-transportation. The final body weight parameter in Table 5 has a body weight gain that was significantly different ($P < 0.05$) between treatments. The daily body weight gain had a significant effect ($P < 0.05$) between each treatment so the significant ($P < 0.05$) daily weight gain of sheep with agricultural waste in the form of silage and wafers was able to increase the average daily weight gain of sheep is because the sheep achieved nutrient adequacy for weighing 15-20 kg according to Kearl (1982). Feed efficiency showed significantly different ($P < 0.05$) conditions between treatments. Feed efficiency is an indicator that states that the higher the feed efficiency value, the higher the rate of increase in body weight. Feed efficiency is the level of feed utilization used to increase the body weight of an animal.

The highest IOFC value was achieved in the wafer treatment (P2) because it had higher feed efficiency so with the use of less feed, it significantly ($P < 0.05$) increased the body weight of the sheep. Because high body weight growth does not necessarily guarantee a maximum profit, but good growth must be accompanied by good feed conversion, as well as affordable feed costs to get optimal benefits. Wafers have a high-efficiency value because of their high dry matter content so they can be given in smaller quantities, but can increase body weight equivalent to silage feed. This is also because in the wafer processing there is heating and compaction which can increase dry matter and reduce particle size so that it is more easily absorbed by livestock. This proves that P2 is more profitable than P0 and P1. Sheep with P1 treatment have recovered with body weight the same as the initial condition of sheep arrival at week 1, while P2 treatment was only able to recover after week 2, and P0 only recovered at week 5. This showed that silage feed can accelerate the recovery of sheep after transportation because silage is easily liked by livestock so livestock can have high feed consumption making high nutrient consumption to accelerate post-transport recovery.

Table 5 showed that logistic feed in the form of silage, pellets, and wafers produced better feed efficiency ($P < 0.05$) than logistic feed in the form of mash. This could be attributed to the feed in the form of mash having a higher intake rate than other forms (Table 2) but was not accompanied by higher body weight gains. This caused the feed efficiency of mash logistics to feed to be lower than other forms of logistics feed. However, logistic feed in the form of silage has a higher feed efficiency value compared to other treatments. Different forms of feed can affect the rate of fermentation in the rumen. These results agreed with Retnani et al. (2022) who revealed that logistics feed in the form of silage provided feed efficiency and higher income. Yanti et al. (2019) added that total mix ration silage derived from agricultural by-products produces fermentation which is well preserved, and this product can be used as ruminant feed.

CONCLUSION

Feeding local sheep with agricultural waste in the form of silage and wafers had a significant effect on the dry matter, crude protein, and crude fat intake and was able to increase final body weights and feed efficiency. Processing of agricultural waste into silage and wafers can improve the performance of local sheep so that agricultural waste has great potential to be used as animal feed.

ACKNOWLEDGEMENT

The authors are thankful to The Indonesia Endowment Funds for Education of Finance Ministry (LPDP); Ministry of Research, Technology and Higher Education Indonesia (KEMENRISTEKDIKTI), and IPB University.

CONFLICT OF INTEREST

All authors declare that there is no conflict of interest.

NOVELTY STATEMENT

Silage and wafer of agricultural waste for improvement performance of local sheep.

AUTHORS CONTRIBUTION

YR, MDE, and MFI conducted the experiment, performed data analysis, and wrote the article draft; IW, DD checked data analysis and revised the article draft; TY and NNB supervised the experiment; HAS, NQ designed the experiment, checked data analysis, and revised the article draft.

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