2026 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 16, Issue 2: 72-81; March 30, 2026

ISSN 2228-7701

DOI: https://dx.doi.org/10.51227/ojafr.2026.9

PHYSICAL PROPERTIES AND NUTRITIONAL QUALITY OF WAFER MADE FROM SUGARCANE BAGASSE-INDIGOFERA MIXTURE AS FEED FOR RUMINANT

Arsyadi ALI[1], Muhammad RODIALLAH[1], Restu MISRIANTI[1], Anwar Efendi HARAHAP[1], Jepri JULIANTONI, and Denis Herian Miswanto Saputra LASE[2]

[1]*Department of Animal Science, Faculty of Agriculture and Animal Science, Universitas Islam Negeri Sultan Syarif Kasim Riau, Pekanbaru, Indonesia*

[2]*Graduated of Faculty of Agriculture and Animal Science, Universitas Islam Negeri Sultan Syarif Kasim Riau, Pekanbaru, Indonesia*

Email: arsyadi.ali@uin-suska.ac.id

Supporting Information

RESEARCH ARTICLE
PII: S222877012600009-16
Received: November 12, 2025
Revised: January 18, 2026
Accepted: January 20, 2026

ABSTRACT: The purpose of this study was to determine the best composition of sugarcane bagasse and Indigofera (legume plant) as main ingredients for wafer formulation for ruminant feed based on physical properties, nutritional quality and palatability. The research was conducted using a complete randomized design (CRD) consisting of 3 treatments with 5 replicates. The treatment was a ration formulation consisting of 6 feed ingredients arranged by the trials and error method with estimated crude protein content (CP) of 12.1-14.2%. The use of Indigofera from 30% to 40% was significantly (P<0.05) improved wafer color score. The use of 35% and 40% Indigofera was significantly (P<0.05) increased the wafer texture score from 3.06 to 3.35. An increase in Indigofera used from 30% to 40% was significantly (P<0.05) improved wafer odor scores. It was found that the difference in the composition of bagasse and Indigofera in wafer formulation gave a significant (P<0.05) difference to the value of wafer density. The difference in the percentage of bagasse and Indigofera in the formulation was not significantly (P>0.05) affecting the water absorption of wafers. The increase in the percentage of Indigofera was significantly (P<0.05) increased the CP and ash content and decreased crude fibre (CF) content of wafer. The increasing in the percentage of Indigofera from 30% to 35% and 40% was significantly (P<0.05) increased in vitro dry matter digestibility (IVDMD), in vitro organic matter digestibility (IVOMD), ammonia nitrogen (NH_3-N) and volatile fatty acid (VFA) total of wafer. The increase in the use of Indigofera from 30% to 35% and 40% in wafer formulations was significantly (P<0.05) lowering wafer palatability in goats. Based on data from physical properties, nutrient content, and in vitro digestibility, it can be concluded that the best wafer formulation was 25% bagasse + 40% Indigofera.

Keywords: Legume, Nutritional quality, Physical treatment, Physical quality, Sugarcane by-product, Wafer formulation.

INTRODUCTION

Sugarcane bagasse (bagasse) is one of energy source for ruminant that is relatively inexpensive (Kaewhom, 2020; Zafeer et al., 2023). Bagasse is a by-product of the sugarcane milling (extraction) proses that contains high crude fibre. Paroha et al. (2020) reported that bagasse's crude fiber and lignin content was 57.55% and 27.22%, respectively. So that bagasse is categorized as roughage feed ingredients. Nevertheless, it is a rich source of cellulose (32–45%) and hemicellulose (20–32%) (Kumar et al., 2021).

Bagasse can be a rich supply of nutritional fibre but its most crucial problem is its low digestibility that is due to association of lignin with cellulose and hemicellulose (lignocellulose). Lignin reduces the digestibility of cellulose and hemicellulose. This limits its use and inhibits its conversion into a source of ruminant animal feed by means of physically protective them against enzyme degradation. Lignocellulose needs to be treated to stretch or break its bond with lignin (delignification). There are several treatments that can be given including physical, chemical and biological treatment. Suryaningrum and Samsudin (2021) found that the use of crude enzyme extract from *B. subtilis* increase protein, dissolved protein, reducing sugars and decrease ash, crude fibre and lignin content in bagasse. Flouring, wafering and fermentation treatments are expected to reduce the crude fibre content of bagasse.

Bagasse cannot be stored for long periods of time nor can it be given directly to beef cattle. Therefore, it is necessary to have feed processing and preservation technology so that bagasse is durable, easy to store, and easy to fed to livestock. One of the feed processing and preservation technologies that can be applied is physical treatment in the form of flour and processed into wafers. Wafer is a form of processed feed that is made in such a way through a pressing process using a felting machine through heating with high temperatures, so that this wafer can be stored for a long time, and is used to overcome the scarcity of forage for ruminant livestock such as goats, sheep and cattle. The advantages of pressed dry feed such as wafer are long shelf life under normal conditions, easy to carry on the way and easily stored (Retnani et al., 2009).

Citation: Ali A, Rodiallah M, Misrianti R, Harahap AE, Juliantoni J, and Lase DHMS (2026). Physical properties and nutritional quality of wafer made from sugarcane bagasse-indigofera mixture as feed for ruminant. *Online J. Anim. Feed Res.*, 16(2): 72-81. DOI: https://dx.doi.org/10.51227/ojafr.2026.9

Improving the quality of complete feed can be conducted by adding protein source feed ingredients to the formulation. Feed ingredients for protein sources that are easily available and cheap are *Indigofera zollingeriana* (indigofera). Indigofera is one type of legume plant that has high protein quality and leaf production. Indigofera biomass contains 20.47-21.39% of crude protein (CP) (Abdullah, 2010) and in vitro digestibility of dry matter and organic matter of Indigofera silage pellet was 70.90% and 70,20%, respectively (Ali et al., 2023). Barokah et al. (2017) reported that the addition of Indigofera biomass to the ensilage process by up to 60% can reduce the crude fibre (CF) content of oil palm fronds silage by 4.67% (from 32.60% to 27.93%). Meanwhile Ali et al. (2023) found that increasing of Indigofera biomass percentage in the formulation can increase the digestibility value and fermentation characteristics of pellets made from palm frond silage and Indigofera biomass. The effect of adding Indigofera on the nutritional quality of bagasse has also been reported by several researchers. Rodiallah et al. (2023) reported that the addition of Indigofera to the complete ration silage made from sugarcane bagasse up to 50% can increase the CP content from 4.27% to 20.85% and decrease CF content from 33.40% to 15.30%. Meanwhile, different results were reported by Ali et al. (2019) the addition of Indigofera biomass by up to 45% did not decrease the fiber fraction (NDF and ADF) content of bagasse silage flour.

The purpose of this study was to determine the best composition of bagasse and Indigofera as main ingredients for wafer formulation for ruminant feed based on physical properties, nutritional quality and palatability.

MATERIALS AND METHODS

Research places

Wafer manufacturing process, physical properties tests, and palatability tests of the wafer were carried out at the Laboratory of Nutrition and chemistry, Faculty of Agriculture and Animal Science, Universitas Islam Negeri Sultan Syarif Kasim Riau (UIN Suska Riau). Proximate analysis and In vitro digestibility tests were carried out at the PAU Laboratory and Dairy Nutrition Laboratory, IPB University.

Materials

The material used was sugarcane bagasse, which was obtained from sugarcane juice traders around Tampan Pekanbaru sub-district of Indonesia. According to Ali et al. (2019), each sugarcane juice trader will produce 3-5 kg/day of bagasse, so that in 100 traders, 300-500 kg of bagasse per day will be produced. Indigofera biomass comes from the experimental field of the Laboratory of Agronomy and Agrostology UIN Suska Riau (Indonesia). Rice bran as a component of rations was obtained from animal feed traders in Pekanbaru City of Indonesia. The tools used for the wafer manufacturing process are choppers*,* flour machines, squeezing machines, plastics, scales, basins, stirring spoons and wafer machine (Figure 1).

Figure 1 - Wafer machines

Livestock

The livestock used for the palatability test were 3 goats weighing 18-20 kg and ± 2 years old. The goats were intensively raised in the stage cage of the Faculty of Agriculture and Animal Science, Universitas Islam Negeri Sultan Syarif Kasim Riau.

Research methods

The research was conducted using a complete randomized design (CRD) consisting of 3 treatments with 5 replicates. The treatment was a ration formulation consisting of 6 feed ingredients arranged by the trial and errors method with an estimated CP of 12.1-14.2%. The composition of the ration which is the treatment is presented in Table 1.

Table 1 - Ingredient of wafer treatment formulation

Feed Ingredients (%) \ Treatment	1	2	3
Bagasse	35	30	25
Concentrate	9	9	9
Rice bran	20	20	20
Indigofera	30	35	40
Molasses	5	5	5
CaCO3	1	1	1
Sum	100	100	100
Estimated CP (%)	12.1	13.15	14.2

Table 2 - Physical properties score of wafers

Physical Properties	Characteristic	Score	Description
Color	Dark brown	3-3.9	Very good
	Light brown	2-2.9	Good
	Brownish yellow	1-1.9	Fair
Texture	Has a firm, dense texture (not easily broken)	3-3.9	Very good
	Has a firm texture, easy to break	2-2.9	Good
	Has a wet texture, easily broken and slimy	1-1.9	Fair
Odor	Smells	3-3.9	Very good
	Odourless	2-2.9	Good
	Rancid	1-1.9	Fair

Source: Solihin and Sutrisna (2015)

Parameters measured

Physical properties

The physical properties measured consisted of the general state of the wafer. The Odor, color and texture of wafer were measured using scores based on Solihin and Sutrisna (2015) (Table 2). Testing of these parameters was carried out by 25 untrained panelists who had an even level of sensitivity and did not receive formal training. Score of density and water absorption of wafer were measured according to Retnani et al. (2010).

The wafer density was calculated by the formula: D = W/(L x Wi xT) (1)

Where, D = Density (g cm^{-3}); W = Weight of test sample (g); L = Length of test sample (cm); Wi = Widt of test sample (cm); T = Thickness of test sample (cm).

The water absorption of wafer was calculated by the formula: WA = ((W2-W1)/W1) x 100% (2)

Where, WA = Water absorption; W1=weight before immersion; W2 = weight after immersion

Nutritional content

The nutrient content in the form of crude protein (CP), crude fiber (CF), ether extract (EE) and ash was measured according to the method of AOAC (2016).

In vitro digestibility and rumen characteristics

In vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) were measured according to Ali et al. (2023). Supernatants from in vitro digestibility tests were collected for the analysis of volatile fatty acid (VFA) total and ammonia-nitrogen (NH_3-N) based according to Ali et al. (2023).

Palatability

The palatability test of the three wafer feed treatments was carried out by looking at the level of feed consumption from 3 goats. The palatability test was carried out by giving each treatment wafer to each goat for one hour of observation every day, namely at 08.00 - 09.00 AM. This observation was carried out for 6 days. The level of palatability of wafers was obtained from how many wafers (g) were consumed by the goats per day.

Wafer manufacturing procedure

Wafer manufacturing was carried out by processing as follows: 1) Collection of bagasse and Indigofera which will be used as raw materials for wafers; 2) Bagasse and Indigofera were cut using *forage chopper* machine with a size of 2-3 cm. It was then dried until its weight is constant; 4) Bagasse and Indigofera were finely ground using a flour mill; 5) Then the two ingredients are weighed and mixed with other feed ingredients (according to the treatment formulation) until they were smooth (homogeneous); 6) The feed material that has been mixed was then molded into a wafer shape using an extrusion machine (wafer machine) which had a wafer printer size of 5 x 5 x 2 cm. Pressing was carried out for 10 minutes at a temperature of 120 °C (Figure 1); 7) Wafer conditioning was carried out by leaving it in the open air (room temperature) until the moisture content and weight of wafer constant.

Statistical analysis

The data from the study results were analyzed using analysis of variance (ANOVA) based on a CRD. Duncan's Multiple Range Test (DMRT) at 5% level was used to determine the difference between treatments.

RESULTS AND DISCUSSION

Physical properties of wafer

The general overview of the wafer results of the study was the weight of one piece of wafer 33 g, with a length of 5 cm, a width of 5 cm, and a thickness of 1.5 (5 cm x 5 cm x 1 cm) so that the volume of 1 piece of wafer is 25 cm^3. With the size of this wafer piece, it was very efficient because it can reduce storage space, make it easier to handle and serve feed. The height of the wafer was lower than the size of the printer. This was because the materials that make up the wafer have particles that can be pressed well. The wafer color score was in the range of 3.04 - 3.25 with very good description (Table 3). The use of Indigofera from 30% to 40% was significantly (P<0.05) improved wafer color score. As illustrated in Figure 2, it can be seen that the composition and percentage of Indigofera affect the color of bagasse wafers.These findings indicate that legume flour can increase the rate of color development. The reason seems to be an increase in the Maillard reaction with an increase in the amino acid content of legume flour (Tufan et al., 2020).

The texture score of the wafer was affected by the level of Indigofera. The use of 35% and 40% Indigofera was significantly (P<0.05) increased the wafer texture score from 3.06 to 3.35 (Table 3). The more portions of Indigofera flour, the smoother the texture of the wafer produced. This was due to the fact that Indigofera flour particles are finer compared to bagasse flour particles. The increase in the use of Indigofera flour in wafer formulation will have an impact on improving the quality of wafers. The fine particles will improve the retention and release of nutrients during digestion due to their larger surface area, which allows for more efficient enzymatic action and better absorption of nutrients (Jima et al., 2025). The texture description based on treatment was illustrated in Figure 3.

The wafer odor produced in this study was in the typical description of wafer smell, with a score range of 3.16-3.35 (Table 3). Good pressure and heating will cause a Maillard reaction so that the resulting wafer was fragrant (typical wafer). An increase in Indigofera used from 30% to 40% was significantly (P<0.05) improved wafer odor scores. This shows that the aroma of wafers was also influenced by the type of ingredients it makes up.

Wafer Density is one important factor in the physical characteristic of wafers that determine wafer strength (Retnani et al., 2010). In this study, it was found that the difference in the composition of bagasse and Indigofera in wafer formulation gave a significant difference (P<0.05) to the value of wafer density (Table 4). The highest density was found in wafer contained of 30% bagasse + 35% Indigofera. This finding indicates that wafer density was not only affected by the particle size of the material but was also affected by the suitability percentage of the material. Meanwhile, Retnani et al. (2009) stated that the density of wafers was also influenced by the density of the constituent materials.

Water absorption is used to gauge the wafer feed's capacity to draw in ambient water (air humidity), which adheres to the material particles or is retained in the pores between the material particles (Sukaryana et al., 2023). The results of study showed that the difference in the percentage of bagasse and Indigofera in the formulation was not significantly (P>0.05) affecting the water absorption of wafers (Table 4). However, the percentage of water absorption tends to decrease with an increase in the percentage of Indigofera. This was due to the lower percentage of Indigofera, resulting in higher wafer fiber content. Retnani et al. (2010) reported that materials with more fibre content that have more air cavity to absorb more water.

Table 3 - Color, Texture, and odor score of wafer

Wafer treatments \ Score	Color	Texture	Odor	Description
T1 (35% B + 30% I)	3.04^{a}±0.37	3.06^{a}±0.33	3.16^{a}±0.33	Very good
T2 (30% B + 35% I)	3.20^{ab}±0.40	3.35^{b}±0.30	3.32^{ab}±0.30	Very good
T3 (25% B + 40% I)	3.25^{b}±0.34	3.35^{b}±0.43	3.35^{b}±0.33	Very good

Note: Means in the same column with different superscripts differ significantly at 5% level; T1=Treatment 1; T2= Treatment 2; T3= Treatment 3; B= bagasse; I= Indigofera

Table 4 - Value of density and water absorption of wafer

Wafer treatments	Density (g/cm³)	Water absorption (%)
T1 (35% B + 30% I)	0.39±0.03[a]	156.42±8.69
T2 (30% B + 35% I)	0.44±0.04[b]	154.11±7.42
T3 (25% B + 40% I)	0.38±0.03[a]	144.89±10.99

Note: Means in the same column with different superscripts differ significantly at 5% level; T1=Treatment 1; T2= Treatment 2; T3= Treatment 3; B=bagasse; I=Indigofera

Figure 2 - Color of wafer treatments: (a) T1; (b) T2; (c) T3

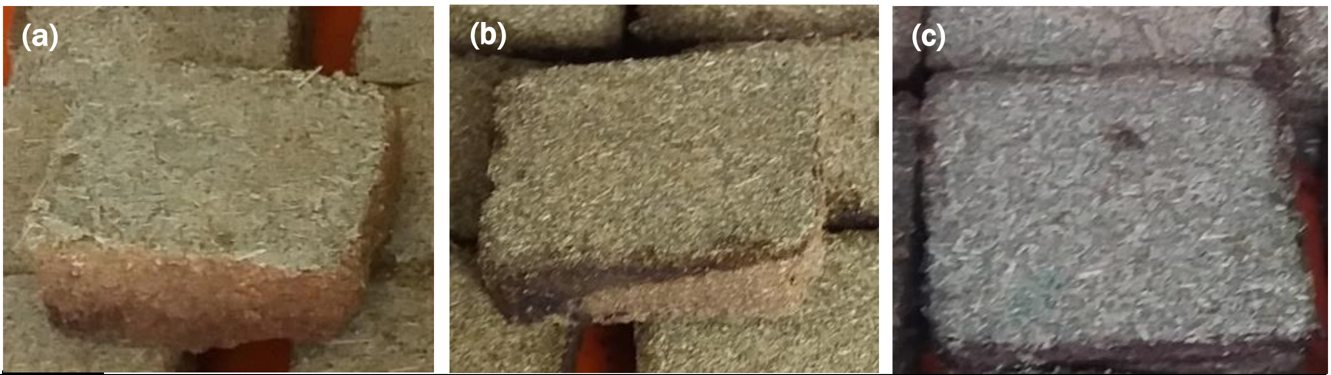

Figure 3 - Texture of wafer treatments: a) T1; b) T2; c) T3

Nutritional Content

The nutritional content of the main constituent ingredients of wafers and treatment wafers is presented in Table 5. Based on Table 5, it can be seen that the moisture content of the wafer in each treatment was less than 11%. This indicated that the process of drying the wafer has been performed effectively. Drying process is a method that effectively reduces the moisture content and play a role in maintaining the stability of product quality (Boateng, 2023; Xu et al., 2024; Zhao et al., 2025). The moisture content of animal feed ingredients that was less than 15% will be able to maintain the quality of the wafer and be safe to store for a long period of time. Low moisture content will limit the reach of microorganisms in the process of spoilage of feed materials (Zambrano et al., 2019; Katu et al., 2025).

Crude protein is a very important nutrient for ruminant livestock, where it supports rumen microbes in degrading feed and that is needed in the growth of livestock body tissues (Ramaiyulis et al., 2019; Sari et al., 2022; Dai et al., 2023; Riaz et al., 2025). The data in Table 5 shows that the increase in the percentage of Indigofera from 30 to 35 and 40% significantly (P<0.05) increased the CP content of the wafer from 10.41% to 12.20% and 13.52%. These results show that every 5% increase in Indigofera can increase the CP content of 1.79% and 1.32%. And the increased use of 10% Indigofera will be able to increase the CP content of wafers by 3.11%. This increase was due to Indigofera containing much higher CP than bagasse. This study corroborates previous research, that to increase the CP content of rouhage and forage low CP content can be added or mixed with forage from protein sources such as legume (Hawu et al., 2022; Castro-montoya et al., 2023; Ebro et al., 2024).

The increasing in the percentage of Indigofera used also significantly (P<0.05) reduced the content of CF Wafer (Table 5). The increasing the percentage of Indigofera from 30 to 35 and 40% can reduce the CF content of treatment wafers from 18.47% to 16.63% and 15.52%. The decrease in CF wafer content for every 5% increase in Indigofera was 1.84% and 1.11% or decreased by 9.96% and 6.67%. The decrease in the percentage of CF wafers with the use of Indigofera from 30 to 40 was 2.95% or significantly (P<0.05) decreased by 15.97%. This shows that the use of bagasse in wafer formulations must be balanced with feed ingredients that have a low CF content such as biomass legume (Indigofera). The low CF content and high CP content of Indigofera make it an excellent material for improving the nutritional quality of animal feed, especially those from agricultural by-products (Ali et al., 2023; Antari et al., 2022; Termizi et al., 2024). The variation in the use of Indigofera in formulations (30%, 35% and 40%) did not have a significant effect on the ether extract content of the wafer, which was in the range of 2.39%-2.62% (Table 5). However, this increase in variation also provides a significant increased (P<0.05) in wafer ash content. This increase was strongly influenced by the mineral content of Indigofera. Ernawati et al., (2021) stated that *Indigofera zollingeriana* could serve as a local legume that provides protein and minerals for livestock.

Table 5 - Nutrient content of bagasse, Indigofera and treatment wafer (%)

Wafer ingredient and treatment \ Nutrient content	Moisture	CP	CF	EE	Ash
Wafer main ingredient formulation					
Bagase	7.96	4.32	23.67	1.51	4.59
Indigofera	10.5	19.76	11.38	4.3	8.83
Treatments					
T1 (35% B + 30% I)	8.69±1.15	10.41^{a}±0.67	18.47^{b}±1.22	2.40±0.13	6.32^{a}±0.22
T2 (30% B + 35% I)	8.22±0.48	12.20^{b}±0.24	16.63^{ab}±0.77	2.39±0.46	6.73^{b}±0.16
T3 (25% B + 40% I)	8.18±0.29	13.52^{c}±0.75	15.52^{a}±0.47	2.62±0.39	7.23^{c}±0.06

Not: Means in the same column with different superscripts on treatments differ significantly at 5% level; T1=Treatment 1; T2= Treatment 2; T3= Treatment 3; B=bagasse; I=Indigofera; CP=crude protein; CF=crude fibre; EE=ether extract

In vitro digestibility

In vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) of bagasse and indigofera wafer and treatment wafer are presented in Table 6. When reviewed from the main materials that make up wafers, Indigofera wafers have higher IVDDM and IVDOM than Bagasse wafers. These results proved that the digestibility of legume was higher than fibre source feed materials such as grass and agricultural industry by-products. Castro-montoya et al. (2023) reported generally, legumes have a higher organic matter (OM) digestibility than grasses. The results of this study showed that the increase in the percentage of Indigofera from 30% to 35% and 40% significantly increased (P<0.05) IVDMD wafer treatment from 67.83% to 70.03% and 72.04%, respectively. The increase in IVDMD wafers at every 5% increase in Indigofera was 2.20% and 2.01% or increased by 3.24% and 2.87%. The increase in the percentage of IVDMD wafers in the use of Indigofera from 30 to 40 was 4.21% or an increase of 6.21%.

Meanwhile, the increase in IVOMD wafers at every 5% increase of Indigofera was 2.23% and 2.00% or an increase of 3.32% and 2.88%, respectively. The increase in the percentage of IVOMD wafer in the use of Indigofera from 30 to 40 is 4.23% or an increase of 6.30%. These results were in line with the reported by Ratnawati et al. (2018), Roca-fernández et al. (2020) and Herliatika et al. (2025) that the use of legumes in the diet can improve the digestibility.

Table 6 - The in vitro digestibility of wafer and characteristics of rumen fluid

Main Ingredient and treatments	In vitro digestibility		In vitro characteristics of rumen fluid		
	DM (%)	OM (%)	pH	NH_3-N (mM/L)	VFA (mM/L)
Wafer main ingredient formulation					
Bagase	54.83	53.62	6.88	5.87	74.78
Indigofera	76.11	75.47	6.78	9.39	115.12
Treatments					
T1 (35% B + 30% I)	67.83^{a}±0.48	67.17^{a}±0.60	6.87±0.008	6.13^{a}±0.14	69.45^{a}±9.86
T2 (30% B + 35% I)	70.03^{b}±0.53	69.40^{b}±0.66	6.80±0.016	7.11^{b}±0.17	94.53^{b}±4.53
T3 (25% B + 40% I)	72.04^{c}±0.32	71.40^{c}±0.54	6.75±0.012	8.35^{c}±0.32	114.65^{c}±10.41

Note: Means in the same column with different superscripts on treatments differ significantly at 5% level. 1=treatment 1; T2= treatment 2; t3= treatment 3; B=bagasse; I=Indigofera; DM=dry matter; OM=organik matter; pH= potential of hydrogen; NH_3-N=ammonia nitrogen; VFA=volatile fatty acid

Characteristics of rumen fermentation

One factor that determines whether the rumen conditions are appropriate for the fermentation process is the pH of the rumen fluid (Zain et al., 2023). The pH value on incubation of all wafer treatments in the present study was in the normal range, namely 6.75-6.88 (Table 6). Mao and Wang (2025) reported that in the rumen, microbial populations flourish within an ideal pH range, usually between 6.0 and 7.0, maintaining a stable and balanced ecology. Therefore, all of wafer treatments provide a balanced pH during the fermentation process thus supporting the ecosystem of microorganisms in the rumen. The pH range should be kept within the normal range. When the pH of the rumen falls below 6, it will result in changes in the environment for rumen microorganisms. This results in a decrease in the growth of fiber-degrading bacteria (Mao and Wang, 2025). When the pH of the rumen rises above 7.5 is referred to ruminal alkalosis, there is decrease in the number of ruminal microflora (Kumbhar et al., 2018).

The total concentrations of NH_3-N and VFA total of bagasse and Indigofera wafers, and treatment wafers are presented in Table 6. The data in Table 6 show that Indigofera wafers have higher concentrations of NH_3-N and VFA total than bagasse wafers. This result was thought to be related to the CP content and carbohydrate structure, where Indigofera has a higher CP content and a lower ADF content than bagasse. Tolera and Sundstùl (2000), and Hristov and Ropp (2003) explained that the high concentration of NH_3-N in the rumen is a consequence of the high protein content in the ration. Meanwhile, the higher ADF content of the cell wall causes carbohydrates to be not digested optimally, which has an impact on the lower concentration of VFA total produced in the carbohydrate overhaul process.

The VFA total of bagasse and Indigofera wafers ranges from 74.78-115.12 mM/L (Table 6) was comparable to the range of VFA total production in the rumen which can reach concentrations of 70-150 mM/L (McDonald et al., 2010). The results also showed that for every 5% increase of Indigofera in wafer formulation was significantly ($P<0.05$) increased the concentration of NH_3-N and VFA total. The percentage increase of NH_3-N concentration in Indigofera used from 30% to 35% and from 35% to 40% was 0.98% and 1.24%, respectively or increased by 15.99% and 17.44%, respectively. And the cumulative increase in the percentage of NH_3-N on the use of Indigofera in ration formulations from 30% to 40% was 36.22%. Meanwhile, the increase in the VFA total concentration at each 5% increase of Indigofera was 25.08% and 20.12% or significant ($P<0.05$) increased by 36.11% and 21.28%. The cumulative increase in the total VFA concentration of wafers on the use of Indigofera in rations from 30% to 40% was 45.20%. Increased use of Indigofera will Increase the protein content of the wafer, which leads to increased protein degradation, thereby increasing the concentration of NH_3-N (Zain et al., 2023).

Palatability of wafer

The palatability test in this study was carried out to find out how much the goats liked wafers made of bagasse with the addition of Indigofera as a protein source. The results of this study showed that increasing the use of Indigofera in wafer formulations from 30% to 35% and 40% was significantly ($P<0.05$) decreased wafer palatability in goats (Table 7). The decrease in the level of palatability reached 30.66 g/day. This may be related to the particle size and texture of the wafer. The higher the percentage of Indigofera, the finer the particle size and texture of the wafer. The study results of (Pujaningsih et al., 2016) indicated that goats prefer forage with larger sizes, especially particle sizes similar to their basal feed. However, goats are one of the livestock that have a high selective nature to feed.

Table 7 - The value of wafer palatability

Wafer treatments	The palatability value
T1 (35% B + 30% I)	$54.83^b \pm 6.82$
T2 (30% B + 35% I)	$24.17^a \pm 1.62$
T3 (25% B + 40% I)	$24.17^a \pm 7.49$

Note: Means in the same column with different superscripts differ significantly at 5% level; T1=Treatment 1; T2= Treatment 2; T3= Treatment 3; B=bagasse; I=Indigofera

CONCLUSION

Based on data from physical properties, nutrient content, and in vitro digestibility, it can be concluded that the best wafer formulation was 25% sugarcane bagasse + 40% Indigofera. The recommendation for further research is to determine the effect of the use of wafers made from bagasse and Indigofera as feed on the intake and weight of goats.

DECLARATIONS

Corresponding author

Correspondence and requests for materials should be addressed to Arsyadi Ali; E-mail: arsyadi.ali@uin-suska.ac.id; ORCID: https://orcid.org/0009-0004-3483-3913

Authors' contribution

A. Ali contributed to performed the experimental and exploring work, literature review, drafted the manuscript; M. Rodiallah contributed to supervised all experiments, preparation and checked the analysis result and manuscript preparation; R. Misrianti contributed to supervised all experiments and manuscript drafting and graphically abstract; A.E.

Harahap contributed to all experiment and manuscript preparation; J. Juliantoni contributed in manuscript drafting and critical revisions; DHMS Lase contributed to all experiment and data analysis. Generally, all authors of the current manuscript are main contributors and have an equal primary role in conducting research according to their fields of expertise and publishing this article in highly reputable and globally indexed journals.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Ethical considerations

This experiment followed research ethics guidelines pertaining to livestock, in accordance with the Animal Science and Health regulations outlined in Government Law No. 41/2014 issued by the Republic of Indonesia.

Acknowledgements

The author thanks to Lembaga Penelitian dan Pengadian Masyarakat (LP2M) and the Faculty of Agriculture dan Animal Science at Universitas Islam Negeri Sultan Syarif Kasim Riau for their support and resources in completing this research.

Funding

The authors declare that no funds, grants, or other support were received during the preparation or publication of this manuscript.

Competing interests

We declare that there are no competing interests with any financial organization regarding the material discussed in this paper.

REFERENCES

Abdullah L (2010). Herbage production and quality of *Indigofera* shrubs treated with different concentrations of foliar fertilizer. Media Peternakan, 33(3): 169–176. https://doi.org/10.5398/medpet.2010.33.3.169

Ali A, Kuntoro B, and Misrianti R (2019). Fiber fraction content of sugarcane bagasse silage meal supplemented with *Indigofera* biomass as feed (Kandungan fraksi serat silase ampas tebu yang disuplementasi biomassa Indigofera sebagai pakan). Jurnal Peternakan, 16(1):10–17. https://ejournal.uin-suska.ac.id/index.php/peternakan/article/view/6213

Ali A, Misrianti R, Roflimas, and Irawati E (2023). In vitro digestibility and gas production of pellets made from oil palm frond and *Indigofera zollingeriana* silage with different compositions. Livestock Research for Rural Development, 35(3): 27. https://www.lrrd.cipav.org.co/lrrd35/3/3527arsy.html

AOAC (2016). Official methods of analysis of the Association of Official Analytical Chemists. Association of Official Analytical Chemists, Virginia. https://www.aoac.org/?s=aoac+2016

Barokah Y, Ali A, and Erwan E (2017). Nutrient content of oil palm frond silage added with *Indigofera zollingeriana* (Nutrisi silase pelepah kelapa sawit yang ditambah biomassa *Indigofera zollingeriana*). Jurnal Ilmu-Ilmu Peternakan, 20(2):59–68. https://doi.org/10.22437/jiiip.v20i2.4772

Boateng ID (2023). A review of solar and solar-assisted drying of fresh produce: State of the art, drying kinetics, and product qualities. Journal of the Science of Food and Agriculture*,* 103(13): 6137–6149. https://doi.org/10.1002/jsfa.12660

Castro-Montoya JM Albarrán-PortilloB, Posgrado, E Agronómicas FDC, Salvador UE, Salvador S, and Salvador E (2023). Digestibility of additional crude protein from tropical legumes in mixed grass–legume rations for ruminants. Chilean Journal of Agricultural and Animal Sciences (Ex Agro-Ciencia), 39(1): 65–74.https://doi.org/10.29393/CHJAA39-6DAJB20006

Dai R, Ma X, Dingkao R, Huang C, La Y, Li X, et al. (2023). Effects of dietary crude protein levels in concentrate supplementation after grazing on rumen microbiota and metabolites using metagenomics and metabolomics in Jersey–yak. Frontiers in Microbiology, 14: 1124917. https://doi.org/10.3389/fmicb.2023.1124917

Ebro A, Alvarez A, Nemera F, Bijdevaate L, Addis H, Demise H, et al. (2024). Inclusion levels of tree and herbaceous legumes on the nutritive quality of grass silage: Results from on-farm trials. Agroforestry Systems, 98(1): 103–113. https://doi.org/10.1007/s10457-023-00893-5

Ernawati A, Abdullah L, and Permana G (2021). Mineral content and uptake of *Indigofera zollingeriana* at different planting densities (Kandungan dan Serapan Mineral Pucuk Indigofera zollingeriana dari Tanaman dengan Kerapatan Tanam Berbeda). *Jurnal Ilmu Nutrisi dan Teknologi Pakan*, 19(2):49–58.https://doi.org/10.29244/jintp.19.2.49-58

Hawu O, Ravhuhali KE, Mokoboki HK, Lebopa CK, and Sipango N (2022). Sustainable use of legume residues: Effect on nutritive value and ensiling characteristics of maize straw silage. Sustainability*,* 14(11): 67-43. https://doi.org/10.3390/su14116743

Herliatika A, Yulistiani D, Puastuti W, Pujiawati Y, Haryati T, Sinurat AP, et al. (2025). Evaluation of feed supplementation using legume leaf meal and spent substrate fermented by *Eupenicillium javanicum* as a potential feed for ruminants: An in vitro study. Journal of Animal and Feed Sciences, 34(1): 78–86. https://doi.org/10.22358/jafs/189327/2024

Hristov AN, and Ropp JK (2003). Effect of dietary carbohydrate composition and availability on utilization of ruminal ammonia nitrogen for milk protein synthesis in dairy cows. Journal of Dairy Science, 86(7):2416–2427.https://doi.org/10.3168/jds.S0022-0302(03)73836-3

Jima BR, Abera AA, and Kuyu C G (2025). Effect of particle size on compositional, functional, pasting, and rheological properties of teff (*Eragrostis teff* [Zucc.] Trotter) flour. Applied Food Research, 5: 100986. https://doi.org/10.1016/j.afres.2025.100986

Kaewhom P (2020). Nutritive value and methods of improving sugarcane bagasse quality for application in animal feeds. Journal of Mahanakorn Veterinary Medicine, 15(2): 131–140. https://li01.tci-thaijo.org/index.php/jmvm/article/view/243669

Katu J K, Toth T and Varga L (2025). Enhancing the nutritional quality of low-grade poultry feed ingredients through fermentation: A review. Agriculture 15: 476. https://doi.org/10.3390/agriculture15050476

Kumar A, Kumar V, and Singh B (2021). Cellulosic and hemicellulosic fractions of sugarcane bagasse: Potential, challenges and future perspective. International Journal of Biological Macromolecules, 169: 564–582. https://doi.org/10.1016/j.ijbiomac.2020.12.175

Kumbhar N, Borikar S, Digraskar S, Shaikh S, and Ajabe J (2018). Occurrence, etiological studies, and clinical findings of ruminal alkalosis in cattle of Parbhani and adjoining areas. Journal of Entomology and Zoology Studies, 6(6): 680–683. https://www.entomoljournal.com/archives/2018/vol6issue6/PartL/6-6-12-851.pdf

Mao J, and Wang L (2025). Rumen acidosis in ruminants: A review of the effects of high-concentrate diets and the potential modulatory role of rumen foam. Frontiers in Veterinary Science, 12: 1595615. https://doi.org/10.3389/fvets.2025.1595615

McDonald P, Edwards RA, Greenhalgh JF D, Morgan CA, Sinclair L A, and Wilkinson R (2010). Animal nutrition (7th ed., 714 pp.). Prentice Hall, New Jersey. https://www.up.lublin.pl/files/animal/ANIM%20NUTR/animal-nutrition_mcdonald_et_al..pdf

Paroha S, Srivastava V P, and Chaturvedi N (2020). Sugarcane bagasse as dietary fibre. Indian Journal of Pure and Applied Biosciences, 8(6): 590–597. https://doi.org/10.18782/2582-2845.8442

Pujaningsih R I, Fani F, and Pambudi AW (2016). Effect of particle size of forage processing technology application on consumption efficiency, palatability, and digestibility of local goats (Pengaruh ukuran partikel pada penerapan teknologi pengolahan hijauan terhadap efisiensi konsumsi, palatabilitas, dan kecernaan kambing lokal). Animal Production, 18(1): 8–13. https://doi.org/10.20884/1.anprod.2016.18.1.529

Ramaiyulis ZM, Ningrat RWS, and Warly L (2019). Protection of Protein in Cattle Feed Supplement from Rumen Microbial Degradation with Addition of Gambier Leaf Residue. International Journal of Zoological Research, 15(1): 6–12. https://doi.org/10.3923/ijzr.2019.6.12

Ratnawati S, Hartutik, and Chuzaemi S (2018). The effect of herbaceous legumes in feed on in vitro digestibility. IOP Conference Series: Earth and Environmental Science, 119: 012012. https://doi.org/10.1088/1755-1315/119/1/012012

Retnani Y, Basymeleh S, and Herawati L (2009). Effect of forage type and storage duration on the physical properties of feed wafers (Pengaruh jenis hijauan dan lama penyimpanan terhadap sifat fisik wafer pakan). Jurnal Ilmiah Ilmu-Ilmu Peternakan, 12(4): 196–202. https://doi.org/10.22437/jiiip.v0i0.169

Retnani Y, Syananta FP, Herawati L, Widiarti W, and Saenab A (2010). Physical characteristics and palatability of market vegetable waste wafers for sheep (Karakteristik fisik dan palatabilitas wafer limbah sayuran pasar untuk domba). Animal Production, 12(1): 29–33. https://www.animalproduction.net/index.php/JAP/article/view/275

Riaz R, Bilal R M, Hassan M U, Todaro M, Gannuscio R, Inal F, et al. (2025). Crude protein degradation kinetics of selected tropical forages in buffalo using NorFor in situ standards. Animals, 15(4): 585. https://doi.org/10.3390/ani15040585

Roca-Fernández AI, Dillard SL, and Soder KJ (2020). Ruminal fermentation and enteric methane production of legumes containing condensed tannins fed in continuous culture. Journal of dairy science, 103(8):7028-7038. https://doi.org/10.3168/jds.2019-17627

Rodiallah M, Harahap AE, Ali A, Adelina T, Mucra DA, Solfan B, et al. (2023). Nutritional profile and fiber fractions of complete silage feed based on sugarcane bagasse with *Indigofera* legume and molasses supplementation (Profil nutrisi dan fraksi serat pakan silase lengkap berbasis ampas tebu dengan leguminosa Indigofera dan suplementasi molases). Jurnal Triton, 14(1): 18–28. https://doi.org/10.47687/jt.v14i1.377

Sari RM, Zain M, Jamarun N, Ningrat RWS, Elihasridas, and Putri E M (2022). Improving rumen fermentation characteristics and nutrient digestibility by increasing rumen degradable protein in ruminant feed using *Tithonia diversifolia* and *Leucaena leucocephala*. International Journal of Veterinary Science, 11(3): 353–360. https://doi.org/10.47278/journal.ijvs/2021.121

Solihin M and Sutrisna R (2015). Effect of storage duration on moisture content, physical quality, and fungal distribution of vegetable- and tuber-waste-based wafers (Pengaruh lama penyimpanan terhadap kadar air, kualitas fisik, dan distribusi jamur wafer berbasis limbah sayuran dan umbi-umbian). Jurnal Ilmiah Peternakan Terpadu, 3(2): 77–83. https://jurnal.fp.unila.ac.id/index.php/JIPT/article/view/767/0

Sukaryana Y, Zairiful, and Panjaitan I (2023). Identification and digestibility of wafer feed based on palm kernel cake in cattle. Proceeding of ABEC, September 21, Bengkalis, Indonesia. https://doi.org/10.4108/EAI.21-9-2023.2342926

Suryaningrum LH and Samsudin R (2021). Improvement of sugarcane bagasse quality as a fish feed ingredient. IOP Conference Series: Earth and Environmental Science, 679: 012003. https://doi.org/10.1088/1755-1315/679/1/012003

Termizi AZAM, Razak ASA, Nasarudin MAS, Hairolnizam NFA, Amalina F, Sulaiman S, et al. (2024). A review of the utilization of *Indigofera zollingeriana* as an animal feed supplement. Construction, 4(2): 118–123. https://doi.org/10.15282/construction.v4i2.118

Tolera A, and Sundstøl F (2000). Supplementation of graded levels of Desmodium intortum hay to sheep feeding on maize stover harvested at three stages of maturity: 1. Feed intake, digestibility and body weight change. Animal Feed Science and Technology, 85(3-4):239-257. https://doi.org/10.1016/S0377-8401(00)00205-4

Tufan B, Sahin S, and Sumnu G (2020). Utilization of legume flours in wafer sheets. Legume Science, 2(1): 1–9. https://doi.org/10.1002/leg3.12

Xu P, Yang Z, Li X, Zhang Z, and Yang J (2024). Effects of different drying methods on drying characteristics and quality of silage *Broussonetia papyrifera* L. LWT – Food Science and Technology, 210: 116872. https://doi.org/10.1016/j.lwt.2024.116872

Zafeer MK, Prabhu R, Rao S, Mahesha GT, and Bhat K S (2023). Mechanical characteristics of sugarcane bagasse fibre reinforced polymer composites: A review. Cogent Engineering, 10(1): Article 2200903. https://doi.org/10.1080/23311916.2023.2200903

Zambrano MV, Duttaa B, Mercerb DG, MacLeana H L, and Touchie MF (2019). Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: A review. Trends in Food Science & Technology, 88: 484–496. https://doi.org/10.1016/j.tifs.2019.04.006

Zain M, Despal, Hidayat U, Tanuwiria Pazla R, Putri EM, and Amanah U (2023). Evaluation of legumes, roughages, and concentrates based on chemical composition and rumen degradable and undegradable proteins using an in vitro method. International Journal of Veterinary Science, 12(4): 528–538. https://doi.org/10.47278/journal.ijvs/2022.218

Zhao C, He Z, Song X, Zhang X, Xiao Y, Yu J, et al. (2025). Evaluation of different drying methods on the quality parameters of *Acanthopanax senticosus* fruits. Foods, 14(7): 1100. https://doi.org/10.3390/foods14071100