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Original Article

Quality of complete feed wafer supplemented with different plant protein sources for small ruminants

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Abstract

Objective: This study aimed to assess the quality of complete feed wafers with different plant protein sources for a feed of small ruminants.
Methods: The research was conducted in May-September 2022. The research method used a completely randomized design (CRD) with 4 treatments and 4 replications. The method used in this study was Completely Randomized Design (CRD) with 4 treatments, namely R0 = Wafer with an animal protein source (Fish meal) (Control), R1 = Wafers with protein source *Sesbania grandiflora*, R2 = Wafers with protein source *Gliricidia sepium*. R3=Wafer with protein source *Leucaena leucocephala*. The research variables consisted of physical quality (moisture content, wafer density, specific gravity, water absorption) and nutritional quality (dry matter, organic matter, crude protein, crude fat, crude fiber, and nitrogen free extracts). Data analysis according to the Analysis of Variance procedure using SPSS version 21.
Results: The results showed that the use of plant protein sources had no significant effect (P>0.05) on water content and wafer density but had a significant effect (P<0.05) on specific gravity and water absorption capacity. The use of plant protein sources can increase the value of water content, wafer density, and specific gravity and reduce water absorption capacity. Meanwhile, the crude protein (CP) content of the wafer had no significant effect (P>0.05) and produced the same value as using fish meal. Other nutritional variables had a significant effect (P<0.05) such as DM, OM, EE and NFE which increased and CF decreased on the use of plant protein sources in making feed wafers compared to the use of fish meal.
Conclusions: It was concluded that the use of legumes *Sesbania grandiflora*, *Gliricidia sepium,* and *Leucaena leucocephala* as a source of vegetable protein in wafers could replace fish meal. The three types of legumes had the same effect on the physical and nutritional quality of the resulting product.

Keywords: *Gliricidia sepium; Leucaena leucocephala;* Quality complete feed wafer; *Sesbania grandiflora*

INTRODUCTION

The ruminant livestock business success is inseparable from the feed availability problem, especially forage. Animal feed availability in sufficient and sustainable quantity and quality are several factors that determine the development of small ruminants, especially Kacang goats. Kacang goat productivity in the tropics generally fluctuates depending on the season [1]. In detail, the availability of feed in dryland areas such as the North Central Timor District in the rainy season will be abundant, while in the dry season, the feed will be very minimal. To ensure the availability of feed, it is necessary to find an alternative feed supply in the dry season. An alternative way that can be utilized is the type of local feed that is quite abundantly available, such as Turi, Gamal, and Lamtoro. *Sesbania grandiflora* (Turi), *Gliricidia sepium* (Gamal), and *Leucaena leucocephala* (Lamtoro) are protein-sourced animal feed with more than 20% protein content. The protein content available in gamal is 21.37% DM [2], lamtoro is 24.95% DM [3], and turi is 31.29 [4]. This high nutritional content can support the production of goats. Generally, protein sources for ruminants come from various ingredients, namely animal protein sources, such as fish meal, shrimp meal, etc. Meanwhile, plant protein sources are composed of legumes such as turi, lamtoro, and gamal. Each ingredient has its advantages and disadvantages. The use of animal protein sources is quite effective because the protein content is relatively high compared to plant protein, but the price is relatively expensive. Meanwhile, plant protein is relatively cheap and easy to obtain (local resources).

In addition to the high nutritional content of turi, gamal, and lamtoro, there is also a disadvantage in the discovery of anti-nutritional content such as tannin, coumarin, and mimosine. Therefore, before being given to livestock, these forages need to be aerated first to reduce the characteristic odor of coumarin in gamal, mimosine in lamtoro, and tannin in turi [5]. based on their growth, generally, turi, gamal, and lamtoro leaves will fall in the dry season if they are not defoliated regularly [6]. Thus, to support the potential of gamal, turi, and lamtoro, it is necessary to make simple technology with a mixture of other local materials to provide good quality feed in the dry season such as feed wafers. Feed wafer is processed using heating and pressing so the product that is dense, compact, and has a high density [7] makes it easier to handle and transport [7,8]. The feed wafer has a complete nutritional content and uses a relatively simple technology so that it is easy to apply. The application of feed wafers can be used to produce ruminant feed that is durable, easy to handle, easy to distribute, easy to feed to livestock, and available throughout the season [9]. Behind the advantages of complete feed wafers, it is necessary to pay attention to their physical and chemical qualities. Therefore, it is necessary to measure or test the physical and chemical properties of complete feed wafers. This study aimed to assess the quality of complete feed wafers with different plant protein sources for a feed of small ruminants.

MATERIALS AND METHODS

Period and location

The study was carried out from May to September 2022 at the Faculty of Agriculture University of Timor. The physical quality test was carried out at the University of Timor while the analysis of the nutrient content was carried out at the feed chemistry laboratory at the University of Nusa Cendana.

Materials and tools

The tools used were wafer molding machines, hammer mills, cutting tools, analytical balances, writing instruments, destruction flask, erlenmeyer flask, electric ovens, rulers, cups, measuring cups, a set of proximate analysis tools, a set of digestibility in vitro analysis tools. The materials used were *Sesbania grandiflora*, *Gliricidia sepium*, *Leucaena leucocephala*, rice bran, corn meal, *Corypa meal*, and mineral mix.

Study design

This study used a Completely Randomized Design with 4 treatments and 4 replications, so there were 16 experimental units. The treatment used is as follows:

R0 = Wafer with an animal protein source (Fish meal) (Control)
R1 = Wafer with plant protein source of *Sesbania grandiflora*
R2 = Wafer with plant protein source of *Gliricidia sepium*
R3 = Wafer with plant protein source of *Leucaena leucocephala*

Table 1. Nutrient content of ingredients for complete feed wafers

Nutrient	Feed ingredient materials							
	Fish meal	*Sesbania grandiflora*	*Gliricidia sepium*	*Leucaena leucocephala*	Rice bran	Corn meal	*Corypa utan*	Field grass
DM (%)	86.02	87.15	84.13	91.1	88.22	85.34	87.15	87.93
OM (%DM)	76.95	80.12	77.43	83.07	76.36	84.03	93.09	76.47
CP (%DM)	26.13	27.24	21.17	25.46	10.21	9.46	10.19	5.25
CF (%DM)	11.25	15.6	12.1	12.56	15.28	4.01	6.13	27.03
EE (%DM)	3.46	7.57	3.25	4.98	8.09	9.06	1.14	0.89
NFE	40.51	28.02	41.08	70.45	42.35	62.17	78.22	42.37

DM= Dry matter; OM= Organic matter; CP= Crude protein; CF= Crude fiber; EE= Ether extract; NFE= nitrogen-free extract content

Table 2. Composition of wafer ingredients

Treatment	Ingredients (%)							
	Fish meal	*Sesbania grandiflora*	*Gliricidia sepium*	*Leucaena leucocephala*	Rice bran	Corn meal	*Corypa utan*	Field grass
R_0	20	-	-	-	10	10	10	50
R_1	-	50	-	-	10	10	10	20
R_2	-		50	-	10	10	10	20
R_3	-	-	-	50	10	10	10	20

The nutritional content of the ingredients for making complete feed wafers and the composition of the wafer ingredients are shown in Tables 1 and Table 2.

Complete feed wafers production procedures

Sesbania grandiflora, *Gliricidia sepium* and *Leucaena leucocephala* were dried in the sun to a moisture content of ±20%. Next, all materials including rice bran, corn, *Corypa meal* and forage are ground using a hammer mill (Jiang Fa brand) until mash size. The milled product is then mixed according to the treatment until evenly distributed (adhesive material directly from *Corypa utan* (starch) and inserted into the wafer molding tool. The wafer printer is made from a 2-ton hydraulic jack modified according to Junaidi [10], rectangular with a size of 2 cm × 2 cm × 1.5 cm. After that, hot pressing is carried out at a temperature of 150°C with a pressure of 200-300 kg/cm2 for 5-10 minutes using a modified hydraulic press machine. Next, the wafer is cooled in the open air for at least 24 hours until the water and weight are constant

Moisture

The moisture content is calculated by the formula:

$$\text{Moisture content (\%)} = \frac{b-c}{b-a} \times 100\% \quad \text{......(1)}$$

Note:
a = The weight of the empty cup (g)
b = The weight of cup + wafer (g)
c = The weight of cup + sample wafer after being oven-dried until its weight is constant (g)

Wafer density

The measurement procedure of wafer density was carried out by weighing the sample (g), measuring the radius (cm), and the thickness of the wafer (cm). Wafer density value can be calculated by the formula [10]:

$$K\ (g/cm^3) = \frac{W}{P \times T \times L} \quad \text{......(2)}$$

Note: K = Density (g/cm^3), W = weight of the sample (g), P = The length of the wafer (cm), L = The width of the wafer (cm), T = The thickness of the wafer (cm)

Specific gravity

Specific gravity is the ratio between the weight of a material to the volume. a total of 20 grams of the sample was put into a 250 ml measuring cup which was filled with 100 ml of distilled water. Furthermore, stirring was carried out to accelerate the loss of air between particles. The measurement of the final volume was carried out after the volume became constant. Specific gravity is calculated by the formula:

$$\text{SG (gr/ml)} = \frac{\text{The weight of a material (g)}}{\text{Aquades volume change}} \quad ......(3)$$

Water absorption

For assessment of water absorption, the test sample was weighed before and after immersion for 5 minutes. The calculation was carried out with the formula [11]:

$$\text{Water absorption (\%)} = \frac{\text{W2-W1}}{\text{W1}} \times 100\% \quad ......(4)$$

Note: W1 = weight before immersion (g); W2 = weight after immersion (g)

Nutrients content

Nutrient contents, namely dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), and crude fiber (CF), were analyzed using the proximate analysis [12], while the nitrogen-free extract (NFE) was calculated by using the formula; NFE = DM − (ash+CP+CL+CF).

Data analysis

The data obtained were analyzed using an ANOVA in a Completely Randomized Design and continued with Duncan's multiple range test to determine the significant difference. Data analysis was carried out using *SPSS version 21* [13].

RESULTS

Moisture

The moisture content resulting from the use of tree legumes as a source of plant protein in the manufacture of feed wafers ranged from 11.78±1.00% (R0) to 12.76±0.22% (R3) (Table 3). The results of statistical tests showed that the treatment had no significant effect (P>0.05). The use of plant and animal protein sources both resulted in the same value of moisture content of the feed wafer.

Wafer density

Wafer density is related to moisture content. If the moisture content has a non-significant effect, the wafer density will also be the same. The wafer density produced in this study ranged from 0.69±0.11 g/cm (R0) to 0.78±0.13 g/cm^3 (R3) (Table 3). Although the treatment had no significant effect, it could be seen that there was a tendency to use legumes as a source of plant protein to produce a higher value of moisture content and wafer density compared to the use of animal protein sources.

Specific gravity

The use of plant protein sources in feed wafers resulted in a higher specific gravity than the use of fish meals. The density of the wafers produced ranged from 0.24±0.01 gr/ml (R0) to 0.39±0.02 g/ml (R3). Table 3 data shows that the treatment has a significant effect (P<0.05).

Water absorption

Water absorption based on Table 3 ranged from 122.53±1.37% (R3) to 138.33±1.98% (R0) and the treatment showed a significant effect (P<0.05). The use of plant protein sources resulted in a lower water absorption value than the use of fish meals as a source of animal protein.

Dry matter (DM) and organic matter (OM)

Based on Table 4, the dry matter ranged from 85.37±1.24% (R0) to 87.76±0.62% (R3) and the statistical test results showed that the use of plant protein sources had a significant effect

Table 3. Physical quality of feed wafers with different plant protein sources

Variables	Treatment			
	R0	R1	R2	R3
Moisture (%)^{ns}	11.78±1.00	12.33±0.54	12.79±0.68	12.76±0.22
Wafer density (g/cm^3)^{ns}	0.69±0.11	0.71±0.99	0.79±0.62	0.78±0.13
Specific gravity (g/ml)	0.24±0.01^b	0.38±0.29^a	0.37±0.01^a	0.39±0.02^a
Water absorption (%)	138.33±1.98^a	122.56±1.03^b	121.55±1.37^b	122.53±1.37^b

Data are presented in the average ±SD; R0 = Wafer with an animal protein sources (Fish meal) (Control), R1 = Wafer with plant protein source of *Sesbania grandiflora*, R2 = Wafer with plant protein source of *Gliricidia sepium*, R3 = Wafer with plant protein source of *Leucaena leucocephala*; ns= not significant.

Table 4. Nutrient quality of feed wafers with different plant protein sources

Variables	Treatment			
	R0	R1	R2	R3
DM (%)	85.37±1.24^{b}	87.62±1.27^{a}	87.97±0.85^{a}	87.76±0.62^{a}
OM (%DM)	77,96±0.90^{b}	80.68±1.23^{a}	81.36±0.55^{a}	80.69±1.05^{a}
CP (%DM) ^{ns}	12.16±1.37	13.18±0.72	13.09±1.32	13.13±0.73
CF (%DM)	22.70±2.06^{a}	20.21±1.76^{b}	17.39±1.20^{b}	17.38±1.46^{b}
EE (%DM)	5.25±0.68^{b}	6.58±0.52^{ab}	6.64±0.42^{a}	6.61±0.58^{a}
NFE (%DM)	30.94±1.23^{b}	32.34±2.25^{ab}	33.31±1.99^{ab}	33.66±1.29^{a}

Data are presented in the average ±SD; R0 = Wafer with an animal protein sources (Fish meal) (Control) R1 = Wafer with a protein source of *Sesbania grandiflora* R2 = Wafer with a protein source of *Gliricidia sepium* R3 = Wafer with a protein source of *Leucaena leucocephala*; ^{ns}= *insignificant;* DM= Dry matter; OM= Organic matter; CP= Crude protein; CF= Crude fiber; EE= Ether extract; NFE= nitrogen-free extract content; ^{ns}= not significant.

(P<0.05) on the level of DM. Likewise, the treatment had a significant effect (P<0.05) on OM levels. In Table 4, the levels of OM produced ranged from 77.96±0.90% DM(R0) to 80.69±1.05 %DM (R3). The use of plant protein sources from legumes resulted in higher DM and OM values than the use of fish meal as a source of animal protein.

Crude protein (CP) and crude fiber (CF)

Based on Table 4, the CP ranged from 12.16±1.37% DM to 13.13±0.73 % DM and the statistical test results showed no significant effect. This means that the use of plant and animal protein sources has the same effect on the CP content of wafers. Meanwhile, the CF ranged from 17.38±1.46% DM (R3) to 22.70±2.06% DM (R0), and the results of the statistical test showed a significant effect (P<0.05). The use of plant protein sources may produce a lower CF value than the control treatment.

Ether extract (EE) and nitrogen-free extract (NFE)

Based on Table 4, the EE values ranged from 5.25±0.68 %DM to 6.61±0.58 %DM. The results of statistical tests showed that EE had a significant effect (P<0.05). Similarly, the NFE levels ranged from 30.94±1.23 % DM to 33.66±1.29% DM which statistically had a significant effect (P<0.05). The use of plant protein sources was able to produce higher EE and NFE values than the control treatment.

DISCUSSION

Table 3 shows that complete feed wafers made from different types of forage legumes produced moisture content that was insignificantly different between treatments. This means that the use of legumes and fish meals as a protein source produces the same moisture content. The similarity of the value of this moisture content is a result of the particle size of the feed and the same compression so that the ability to absorb and store water is also the same. However, the moisture content produced can be tolerated because if the moisture content is higher, it may provide an opportunity for microorganisms to grow. According to Trisyulianti *et al*. [14] the moisture content of wafers is influenced by the moisture content of the material, the humidity of the air, and the compression temperature and compression pressure. In this study, the moisture content of the air humidity, compression temperature, and compression pressure given was the same so it resulted in the same moisture content value. The moisture content is related to the use of *Corypa* meals, which *Corypa* meals contain starch that can bind water because of its hydroxyl content. This is strengthened by Khairunnisa *et al*. [15]. The results showed that the moisture content in each treatment had no significant effect. This is related to the previous reason that the nature of starch in addition to its gelatinization effect can also absorb water.

Wafer density is related to the impact resistance of the wafer which is needed to determine the quality of the resulting wafer [7]. Wafer density is determined by the particle size and moisture content of the material. If the particle size is getting smaller, the wafer density will be higher and vice versa. The larger particle size causes the cavity formed to be wide (cannot be tightly packed) so that the evaporation of water will become faster [16]. Moreover, the feed particle size of 10-20 mm can provide the best wafer physical appearance. Meanwhile, if the moisture content in the feed ingredients is high, the wafer density will be low. Pratama *et al*. [17] stated that the moisture content contained in the feed material will also affect the density of the wafer. Generally, an increase in the moisture content of a material causes a decrease in its density of the material. The moisture content in the wafers as shown in Table 3 shows a non-significant difference so that the wafer density is also the same. In addition to particle size, the type of -adhesive used also has an effect, as reported by Rahmadan *et al*. [18] on the use of tapioca by-product as adhesive, and Adli *et al*. [19] who compared molasses, tapioca by-product, and tapioca. The report showed that each material used as an adhesive in the manufacture of wafers produced a different density and water absorption capacity. So that the use of adhesives can be adjusted to the needs and availability of materials. In this study, adhesives were used from the starch found in corypa or corn meal. Starch can cause stickiness or gelatinization if given a certain heat and pressure or the heat generated from the given pressure. This is following Sistanto *et al*. [20] that starch consists of amylose which can give hard properties as well as amylopectin which causes stickiness.

The density of wafers produced in this study is almost the same as those reported by Rahmadan *et al*. [18] which ranged from 0.75-0.76 g/ml on complete feed wafer with corn straw, and the report of Islami *et al*. [21] which produces a specific gravity of ratoon wafer with a mixture of nature grasses of 0.67-0.84 g/ml. The existence of "the similarity in the range of wafer specific gravity is related to the type of material which is generally derived from grass and a mixture of other materials. According to Islami *et al*. [21], the higher the specific gravity of the wafer, the easier it will be to separate or less stick. Moreover, Salam [22] stated that feeding ingredients with the same particle size and mixing the same particle materials will increase the specific gravity of the wafer. The use of legumes in R1, R2, and R3 with the same particle size and mixing obtained the same effect on the density of wafers. Differences in particle size which are then mixed and ordered will be easily separated, in contrast to the same feed particle size will be tightly bound.

Water absorption is related to the thickness of the wafer. The greater the water absorption capacity due to the expansion of the material particles that interact with water [14]. From this study, the water absorption capacity was 121.55-138.33 and the use of legumes resulted in lower water absorption than the control treatment. Fibrous forage can absorb water because it has bonds and an area of contact between particles. The water absorption capacity in this study was lower than that reported by Trisyulianti *et al*. [14] which resulted in water absorption ranging from 170%-178%. This is related to the pressure applied during wafer printing. If the pressure applied is greater, less water absorption is produced because there is no space for the feed particles to absorb water. However, the smaller compression pressure provides an opportunity for the feed particles to absorb water. In this study, the pressure applied was 200-300 kg/cm^2 while Trisyulianti *et al*. [14] used a pressure of 100-140 kg/cm^2.

In general, forage legumes such as lamtoro, turi and gamal lose their leaves during the dry season if they are not defoliated regularly, but in the rainy season, their availability is abundant. This condition may result in low livestock production in the dry season so feed processing can be an alternative to provide feed throughout the season. Feed processing can maintain quality, improve palatability, and be effective in feeding to livestock [23]. Table 4 shows that the nutritional content of feed wafers with different protein sources suggested different effects between control (R0) and other treatments (R1, R2, and R3). DM of wafers on R1, R2, and R3 are quite high and different from R0. This is due to the use of -legumes forage can maintain and increase the dry matter content of wafers. In general, forage in the form of legumes has a high nutritional content, especially in crude protein and dry matter that is easily digested, thus the DM was high in the treatment. The content of DM in this study might be able to meet the needs of small ruminants such as goats.

However, in this study, DM levels were higher than those reported by Purba *et al*. [24] with a DM range of 75.1%-77.7% on complete feed wafers originating from oil palm waste. The difference in the material and size of the wafer is one factor that causes the difference in DM content. Similarly, the use of *Corypa meal* can absorb water thereby resulting in high DM. The OM content value was in line with the content of DM. Generally, OM is a component contained in DM [25] so if the DM content is high, OM is also high.

The CP content of wafers in this study ranged from 12.16% to 13.18% and could be categorized as sufficient for the growth of goats. Haryanto and Djajanegara [26] stated that growing goats need CP in the feed ranging from 12-15%. According to Retnani *et al*. [7], the protein content of feed wafers ranges from 12 to 14%. The use of legumes such as *Sesbania grandiflora*, *Leucaena leucocephala*, and *Gliricidia sepium* as a source of plant protein resulted in CP content which was insignificantly different from treatment using a fish meal. This suggested that the use of fish meals as a source of animal protein in wafers can be replaced by the use of legumes as a source of plant protein because the CP produced is relatively the same. The use of plant protein sources in feed can make a big contribution for several reasons such as being cheap, easy to obtain, and available in the community. The CP content in this study was not much different from that reported by Mucra *et al*. [27] on complete feed wafer substituted with corn bran and the sago meals which resulted in CP levels of 11.92%-13.92%. This is because these studies used similar materials but different sources of starch and adhesive.

The use of legumes as a protein source in making wafers resulted in lower CF values than controls. This indicated that the balance between grass and legumes may result in lower CF levels. The level of CF in the wafer depends on the use of the material. If the ingredient contains high CF, the CF content in the wafer will also be high. In ruminants, CF content is important due to the stability of the rumen condition as a result of rumination carried out to produce saliva which can contribute to enzymes needed by rumen microorganisms and metabolic processes in the body. The content of this CF is almost the same as the study reported by Sari *et al*. [28] on wafers using Hymenachae amplexicaulis with different adhesives and storage times of 17.99%-21.06%.

The use of different types of legumes in making wafers was significantly higher in producing EE. This is related to the available EE content in the materials. The EE content in this study was greater than the EE content reported by Rostini *et al*. [29] on wafers used in waste of palm oil and legume plants by 0.67%. As previously stated, the EE content of the constituent materials also affects the EE of wafers. While the NFE on the use of legumes was significantly higher than using a fish meal. According to Sari *et al*. [28], if the NFE is less, the less organic matter components can be digested. NFE is soluble carbohydrates, namely monosaccharides, disaccharides, and polysaccharides, with high digestibility levels [30]. Therefore, high NFE content will cause a high digestibility level, there by providing energy for animals. The NFE data showed that wafer using legumes is significantly higher than using fish meal, and is expected to increase animal digestibility.

CONCLUSION

The use of *Sesbania grandiflora*, *Gliricidia sepium*, and *Leucaena leucocephala* as a source of plant protein in wafers can replace fish meal utilization. Three types of legumes have the same effect on the physical and nutritional quality of the wafers.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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