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Complete Wafer Physical Quality Test Based On Mung Bean Sprout Husk Waste

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***Abstract**. Mung bean sprout husk is waste with promising nutritive value (crude protein 14%, Total Digestible Nutrients 64.58%, moisture 63.35%) and, due to its high moisture, is suitable for processing via feed-wafer technology. This study aimed to evaluate the physical quality and identify the best storage duration of complete wafers formulated with mung bean sprout husk. A completely randomized design with four treatment levels (0%, 10%, 20%, 30%) and three replicates was used. Organoleptic traits were described descriptively, while physical traits density, water absorption, impact resistance, and wafer durability index (WDI) were analyzed by one-way ANOVA followed by Duncan's Multiple Range Test ($\alpha = 0.05$). Supplementation of mung bean sprout husk significantly affected density and water absorption ($P < 0.05$), with the 30% treatment achieving the highest density ($0.57\ g{\cdot}cm^{-3}$) and water absorption (83.0%), both superior to the control ($P < 0.05$). In contrast, impact resistance (99.1%) and WDI (85.8%) did not differ among treatments ($P > 0.05$). Overall, the 30% supplementation delivered the best physical quality and the best storage duration among the tested formulations.*

***Keywords:** Complete wafer, Feed, Physical quality, Mung bean, Sprout husk*

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INTRODUCTION

The limited availability of feed ingredients encourages innovation in the use of market waste as an alternative source of animal feed. Vegetable waste commonly found in the market includes cauliflower leaves, mung bean sprout husks, and corn husks which can be used as animal feed (Wolayan et al., 2017). Mung bean sprout husk is waste product from sprout production. Mung bean sprout husk can be used as an alternative feed ingredient with a fairly high nutrient content (Puspitasary et al., 2018). The mung bean sprout husk contains around 14% protein; crude fiber 33.1%; fat 0.2%; water 63.35%; and *Total Digestible Nutrients* (TDN) 64.58% (Wyandhana et al., 2019). The high moisture content of mung bean sprout husk can reduce storage time. Deficiencies in mung bean sprout husk can be overcome by processing through the drying process and using them as ruminant feed products.

One of the innovative processing technology that can be applied in the utilization of mung bean sprout waste is through the production of wafers (Hermawan et al., 2015; Febrian, 2021). Wafer is one of the effective feed processing technologies and is expected to maintain the continuity of animal feed, especially in the dry season. Wafer has a dense and compact shape that makes it easy to store and handle and is preferred by livestock (Harahap et al., 2021a; Retnani et al., 2022).

Ruminant wafers are a sustainable approach in the field of livestock by utilizing available agricultural resources efficiently while improving feed quality. The use of mung bean sprout husk waste with wafer technology has not been widely practiced. The composition of wafer production can affect on quality. Based on this potential, this study aims to observe the physical quality of complete wafer based on mung bean sprout husk waste.

LITERATURE REVIEW

1. Wafer Feed

Wafers are a quantitative mixture of all feed ingredients consisting of protein sources, energy sources, fiber, vitamins and minerals formulated in the desired proportions to meet specific nutritional requirements so that livestock do not experience nutrient deficiencies. The ideal nutrient standard on wafer has an average moisture content ranging from 9-15%. Protein source are essential as the main component in complete feed wafers ranging from 15-20% (Retnani et al., 2020).

Fillers are components of wafer feed consisting of forage, legumes, concentrates and minerals. Forage sources that can be used include elephant grass *(Pennisetum purpureum sp.)*, lamtoro legume *(Leucaena leucocephala)*, market waste of mung bean sprout husk, rice bran and bran, as well as premix and salt as mineral sources. Binder materials or commonly known as *binders* aim to unite the material components to produce a strong, compact, and stable shape. The recommended binder for wafer production are molasses with a usage percentage of 5-15% and tapioca flour of 9% (Prasetyani, 2021).

According to Retnani et al. (2020), the wafer manufacturing process consists of several stages, namely *grinding*, *formulation*, *mixing*, *heating and pressing*, and *cooling*. In simple term, the wafer manufacturing process begins with chopping, mixing and ends by printing using a press machine (Samara *et al*., 2024).

The advantages of wafers are reduce storage space, reduce transportation costs, facilitate feed handling and presentation, increase feed consumption, make it easier to control, and consistent and guaranteed nutrients, as well as reducing dust and respiratory disorders in livestock (Ara et al., 2024). The disadvantage of wafer is requires additional costs that affect production costs (Islami et al., 2018).

2. Physical Quality of Wafer

The physical quality of the wafer is a parameter that generally describes the effectiveness and storage time of the wafer. Physical quality testing is a basic test to determine feed accepted in the feed industry. Physical qualities include color, odor, texture, fungi, density value, water absorption, and impact resistance as well as *wafer durability index.*

3. Packaging and Storage

Packaging is done to protect the feed from various factors that can cause quality deterioration during storage. Each type of packaging has different texture conditions, so the ability of wafers to absorb water depends on the type of packaging used (Harahap et al., 2021b). Plastic packaging as a packaging material has the advantage of being strong and selective in its permeability to water vapor, O_2 and CO_2. Storage is a form of safety measure related to the time period for maintaining and preserving quality by avoiding, reducing or eliminating various factors that can reduce product quality and quantity of products (Ara et al., 2024).

RESEARCH METHODS

Location and Time

This research was carried out, from March to April 2025. The production and physical quality test as well as storage of wafer were conducted at the Animal Nutrition Laboratory, Department of Animal Husbandry, Faculty of Agriculture, Mulawarman University.

Materials

Materials used in wafer production include elephant grass *(Pennisetum purpureum sp.)*, lamtoro leaves *(Leucaena leucocephala)*, mung bean sprout husk waste, rice bran, bran, molasses, tapioca flour, salt and premix. Mung bean sprout husk waste is obtained from the Segiri market in Samarinda. Physical quality testing using distilled water and aluminum foil. The tools used in wafer include digital scales, blender, molds, iron plates, *press* tool and oven. Physical quality testing uses measuring instruments such as calipers, trays, iron plates or plates and 24×11 cm plastic boxes. The wafers are packaged and stored in plastic packaging (*standing pouch).*

Research Methods

This study used a Completely Randomized Design (RAL) with 4 treatment levels of mung bean sprout husk waste and 3 replicates. The mung bean sprout husk waste usage levels were 0%; 10%; 20%; and 30%.

Procedures

1. Forage Drying

Forage sources such as elephant grass, lamtoro leaves, and mung bean sprout husk waste were dried to reduce moisture content. This technique aims to prevent fungal growth and the risk of quality degradation in feed wafers.

2. Wafer Ration Formulation

The ration formulation was adjusted to the needs of beef cattle with a body weight of 300 kg and crude protein (CP) of 10% and TDN of 60% (NRC, 2000). The following is the ration formulation and nutrients in complete wafers.

Table 1. Formulation and Nutrient Content of Complete Wafer

Feed Ingredients	Treatment (%)			
	P0	P1	P2	P3
Elephant Grass	30	20	10	5
Lamtoro Leaves	10	10	10	5
Mung bean Sprout husk	0	10	20	30
Rice bran	15	15	15	15
Bran	28	28	28	28
Molasses	5	5	5	5
Tapioca Flour	9	9	9	9
Salt	0,5	0,5	0,5	0,5
Premix	2,5	2,5	2,5	2,5
Amount	100	100	100	100
Nutrient Content (%)				
Dry matter	52,32	50,29	48,26	45,14
Ash	8,16	7,24	6,32	5,64
Crude protein (PK)	14,96	15,29	15,62	15,26
Crude fat (LK)	3,89	3,70	3,51	3,30
Crude fiber (SK)	16,83	16,72	16,61	17,44
Total digestible nutrient (TDN)	67,71	67,23	66,75	65,94
Ca	4,67	4,63	4,59	4,47
P	1,47	1,46	1,46	1,45

Description : P0: Ration + without the addition of mung bean sprout husk waste, P1: Ration + 10% mung bean sprout husk waste, P2: Ration + 20% mung bean sprout husk waste, P3: Ration + 30% mung bean sprout husk waste.

3. Ingredient Mixing

All ingredient derived from forage, concentrates, minerals and binder were weighed based on the formulation and requirements that had been prepared. Mixing of filler ingredients began with the smallest weight to the largest weight to ensure even or homogeneous mixing. Then, grind the ingredients using a blender until they become smaller particles. The adhesive materials, namely molasses and tapioca flour, are added to 70 ml of water or equivalent to 1:5 (Ara et al. 2022). Then, mix little by little with the filler ingredients.

4. Wafer Production

After all the ingredients are well mixed, put them into a square mold with a size of 20×20 cm with a depth of 5 cm and place an iron plate on top of the mold. Perform this procedure alternately for all treatments. Then, press the wafer at a temperature of around 150^{o} C during 15 minutes. Perform two pressings to achieve good adhesion.

Once done, the wafer are dried in oven for 2 days at a temperatur of 60-65^{o} C until weight becomes constant (Awaliah, 2020).

5. Storage Time

Wafers were stored duration in *standing pouch* packaging for 0 weeks, 2 weeks and 4 weeks. Storage condition at room temperature 25-26^{o}C. Each *standing pouch* contained one of wafer. Observe the condition of wafers for fungal growth during storage.

6. Wafer Physical Quality Test

a. Fungi, Color, Odor and Texture

Table 2. Physical Criteria of Wafer

Criteria	Characteristic	Score
Number of Mushrooms	Moldy	1
	Slightly moldy	2
	Non-moldy	3
Color	Brownish yellow	1
	Light Brown	2
	Dark Brown	3
Odor	Rancid	1
	Odorless	2
	Typical molasses	3
Texture	Wet, breakable, slimy	1
	Dry, breakable, non-slimy	2
	Dry, dense, non-slimy	3

b. Density

Density is a description of the desired wafer density. The density value is measured using a caliper. Density measurement used the method describe by Silaban et al. (2020).

$$K = \frac{W}{(P \times T \times L)} \times 100\%$$

Information:

K: density (g/cm3); W: test weight(g); P: test length (cm); T: thickness (cm); L: width (cm).

c. Water Absorption

Water absorption was obtained from the weight measurement of the wafer before and after being immersed in distilled water for 5 minutes. Water absorption testing is carried out using the method described by Silaban et al. (2020).

$$DSA(\%) = \frac{Weight\ after\ immersed - Weight\ before\ immersed}{Weight\ before\ immersed} \times 100\%$$

d. Impact Resistance

Impact resistance is measured by dropping a wafer from a height of 1 meter on iron plate. The test was conducted using the method described by Syahri (2018).

$$Impact\ Resistance\ (\%) = \frac{Weight\ of\ wafer\ after\ dropping}{Weight\ of\ wafer} \times 100\%$$

e. Wafer Durability Index (WDI)

This test is one of the indicators of the success of wafer production in terms of resistance to impacts, shocks and drops. WDI is measured by putting wafer into a plastic box and then shaking it at 5 rpm for 3 minutes (Hasanah, 2023).

$$WDI\ (\%) = \frac{Weight\ of\ wafer\ after\ shaking}{Weight\ of\ wafer} \times 100\%$$

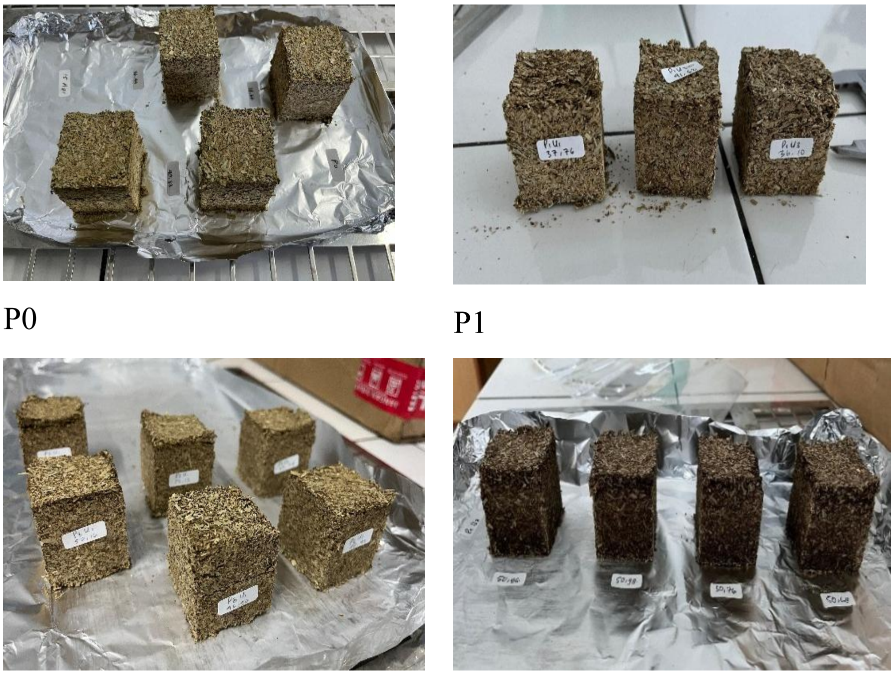
7. Data Analysis

The research data was analyzed by 2 methods, namely descriptive for physical quality parameters such as fungi, color, texture, and odor of complete ruminant wafers. Meanwhile, physical qualities such as density, water absorption and impact resistance values as well as *wafer durability index* were used by quantitative method with analysis of variance (ANOVA) and continued by *Duncan's Multiple Range Test* (DMRT) if there were significant difference between treatments. Software for data analysis with SPSS.

RESULTS AND DISCUSSION

1. Organoleptic of Wafer

The physical appearance of the wafer based on mung bean sprout husk waste presents different qualities. The following is the physical appearance of the wafer which can be seen in Figure 1.



P0 P1

P2 P3

Figure 1. Physical Appearance of Complete Wafer

The following results of color, aroma and texture tests on complete wafers based on mung bean sprout husk waste can be seen in Table 3.

Table 3. Complete wafer color, aroma and texture test results

Indicators	P0	P1	P2	P3
Color	Yellow-brownish	Light Brown	Dark Brown	Dark Brown
Odor	Molasses	Molasses	Molasses	Molasses
Texture	Densely Packed	Breakable	Breakable	Densely Packed

Description: P0: Ration + without the addition of mung bean sprout husk, P1: Ration + 10% mung bean sprout husk, P2: Ration + 20% mung bean sprout husk, P3: Ration + 30% mung bean sprout husk

Color

The physical appearance of the wafer color based on Table 3 shows that the increase in the percentage of mung bean sprout husk waste as the constituent material of the wafer gives it a darker color. P2 and P3 treatment, wafer color tends to be darker or dark brown when compared to P0 (yellow-brown) and P1 (light brown). The drying process of mung bean sprout husk is influenced by temperature and drying time which results in *browning sections* which affect the color of the wafer. The color difference produced by each treatment is according to the statement (Harahap et al., 2021a; Akbar et al., 2023) that wafer based on agricultural waste has a light brown to dark brown color influenced by the composition and type of agricultural waste that has gone through the drying process. In addition, the brown color of the wafer comes from the use of an adhesive material, namely molasses (Nasution et al., 2021). The maillard reaction occurs because carbohydrate and protein compounds are heat-treated causing a reaction between amino acids and reducing sugars, which forms brown pigments (Hasanah, 2023). The maillard reaction occurs from a temperature of 37°C and a maximum at 100°C and stops at a temperature of 150°C. Brown is considered the optimal color and not an aberration (Azizah et al., 2023).

Aroma

Based on Table 3, all treatments produce the same odor, namely molasses. Molasses has a fragrant and sweet odor. The aroma of feed that is preferred by livestock is fragrant, fresh and not rancid which can increase feed palatability and acceptance by livestock (Ismi et al., 2017; Handayani et al., 2019). The odor of wafer comes from the heating process of wafer ingredients which consist of waste and starch-containing materials, as well as adhesives that strengthen the odor of wafer original, which is characterictic of caramel (Harahap et al., 2021a). The duration of heating does not cause a difference in the odor in the wafer produced because the temperature used is still normal and the heating time is relatively short so that it does not cause a burnt odor (Rokana et al., 2022).

Texture

The physical appearance of the wafer texture based on Table 3 shows different results. The texture produced by P0 and P3 is rough and dense. When compared to P1 and P2, this treatment produces a rough and breakable wafer texture because the use of elephant grass and mung bean sprout husk have a combination of different chopping textures so that the density value decreases which results in the wafer being breakable. This is supported by the statement of Harahap *et al*. (2021b) that the texture of the feed can be seen from the smooth, fibrous, or perforated surface of the feed. Feed wafers are breakable because the feed ingredients have undergone chopping and grinding process, resulting smaller and more fragile particles even through adhesive have been added to wafer (Azizah et al., 2023). The dense or breakable texture of wafer is influenced by the density of the raw materials used and pressure and heating time of the pressing carried out. The texture of the wafer is affected by the raw material, the thickness of the mold, the heating time and the temperature of the machine (Rokana et al., 2022).

Physical quality is classified into several parameters, namely density values, water absorption, and impact resistance as well as *wafer durability index*. The results of the physical quality test of the complete wafer based on mung bean sprout husk waste can be seen in Table 4.

Table 4. Results of physical quality test of complete wafer

Variables	P0	P1	P2	P3
Density (g/cm^3)	0.40±0.02^a	0.49±0.02^b	0.54±0.02^b	0.57±0.02^c
Water Absorption (%)	59.55±6.11^a	42.95±8.64^a	71.23±3.77^b	83.00±1.06^c
Impact resistance (%)	97.23±0.02	84.80±0.14	87.67±0.10	99.13±0.01
Wafer durability index (%)	98.33±0.01	89.73±0.13	92.90±0.05	85.80±0.23

Description: P0: Ration + without the addition of mung bean sprout husk, P1: Ration + 10% mung bean sprout husk, P2: Ration + 20% mung bean sprout husk, P3: Ration + 30% mung bean sprout husk. Different superscript letters on the same line indicate a significant differences (P<0.05).

1. Density

The results of the analysis of variance showed that the addition of mung bean sprout husk waste had a significant effect (P<0.05) on the density of feed wafers. Based on the results of the DMRT follow-up test, it shows that P0 is significantly different from P1, P2, and P3. The lowest density value was in P0 with an average of 0.40 g/cm^3 and the highest in P3 with an average of 0.57 g/cm^3. The highest density in P3 is due to the wafer ingredients being legumes from lamtoro leaves and mung bean sprout husk waste which have fine particle size, resulting in good compaction (Febrian, 2021). The density value in P3 is directly proportional to the resulting texture, which is dry and dense. The results of this study are higher than the gamal and lamtoro wafer research, which is 0.41 g/cm^3 (Soi, 2020). The good density is 0.69 g/cm^3 (Rahmadan et al., 2021).

According to Arsadianti et al. (2024), the factors that affect density are seen from the temperature and pressure of the pressing used as well as the adhesion to the feed wafer so that a good wafer product (Syahrir et al., 2017). High density wafers provide a denser and harder texture so that it can reduce the palatability of livestock because the livestock takes longer to consume the wafer. Conversely, low density wafers show a shape that is not too dense, more brittle and has void (Silaban et al., 2023) and is easily damaged during transportation and storage (Islami et al., 2023). The application of wafer feed can be given directly or soaked to make it easier for livestock to consume (Indriani et al., 2024).

2. Water Absorption

The results of the analysis of variance showed that the addition of mung bean sprout husk had a significant effect ($P<0.05$) on the water absorption capacity. Based on the results of the DMRT follow-up test, it showed that P0 was not significantly different from P1 but was significantly different from P2 and P3. The lowest water absorption in this study was P1 with an average of 42.95% and the highest in P3 which was 83.00%. The average value of wafers based on mung bean sprout husk waste is lower than the research of Islami et al. (2023) wafers based on corn forage and gamal legumes with an average yield of water absorption ranging from 67.42% - 99.20%.

Fiber based feed has more air pockets, the more fiber used, the more particle expansion occurs which weakens the bonds between particles (Rostini et al., 2017). Wafers made from mung bean sprout husk waste have relatively high absorption due to the content of hydrophilic groups that retain moisture. In addition to the use of constituent raw materials in wafers, water absorption is affected by adhesives (Adli et al., 2022). A complete ration wafer with high water absorption makes the dimensional stability of the wafer soft and quickly destroyed, meaning that the wafer will not withstand storage for a long time (Herryawan et al., 2021; Islami et al., 2018).

Water absorption that is too low below 50% causes livestock to have difficulty consuming feed because dense wafer conditions are difficult to decompose by saliva or saliva in livestock (Azizah et al., 2024). This has an impact on the efficiency of livestock saliva to be able to soften feed and facilitate the mastication process in livestock (Silaban et al., 2023).

3. Impact Resistance

The results of the analysis of variance showed that the addition of mung bean sprout husk had no significant effect ($P>0.05$) on the impact resistance produced. The lowest impact resistance in this study was P1 with an average of 84.80% and the highest in P3 with an average of 99.13%. P3 treatment, the wafer does not undergo breakage compared to P0, P1 and P2 with the number of broken wafers that are 1, 2 and 3 respectively. Wafers with the addition of 30% green bean sprout husk waste provide better physical performance than the others. This study is higher than feed wafers made from mini elephant grass and indigofera legumes with an average value of 97.89%

(Azizah et al., 2024) and wafers based on peanut shell waste with a value of 91.6% (Hasanah, 2023).

Impact resistance can be affected by particle size, adhesive material and pressing temperature (Hadi et al., 2020; Jaelani, 2016). The strength of the wafer is determined by the bond of each particle consisting of the fiber arrangement, and the smaller surface area so that the use of adhesive materials is more efficient and beneficial to the physical wafer (Akmal and Mairizal, 2020). The addition of binders or adhesive materials can minimize wafer breakage during the storage process (Adli et al., 2022; Syahri et al., 2018). The longer the heating time causes molasses adhesives to work more effectively to attach material particles (Rokana, 2022).

4. *Wafer Durability Index* (WDI)

The results of the analysis of variance showed that the addition of mung bean sprout husk had no significant effect ($P>0.05$) on the *wafer durability index* produced. The lowest WDI value was in P3 with an average of 85.80% and the highest in P0 with an average of 98.33%. In treatments of P0 and P2, two samples of wafers broke while in treaments P1 and P3 only one sample of wafer broke in each treatment. The ration wafer with the addition of 10% and 30% of mung bean sprout husk waste performed quite good physically compared to P0 and P2.

Excessive drying of forage allows for breakage that occurs in wafers. The natural adhesion process by the moisture content of the forage constituent material affects the compactness of the wafers produced. The low moisture content provokes a more fragile texture change. The drying process causes changes in the characteristics of the product chemically and sensorially (Pasaribu, 2023).

The use of tapioca flour as a wafer adhesive material based on mung bean sprout bark waste can help the adhesion of particles. Tapioca flour contains 17% amylose and 83% amylopectin (Muin et al., 2017). Hardness is caused by amylose while stickiness is caused by amylopectin. This research also uses starch materials such as rice bran and bran that support wafer adhesion. The gelatinization process during heating produces wafers with a strong, sturdy and compact structure. A high WDI value will be resistant to friction and shock, if the lower the value the wafer will be more crumbly, less dense and easily destroyed (Rahmadan et al., 2021).

This research is much higher with a complete wafer based on peanut shell waste with a value of 81.3 – 87.1% (Hasanah, 2023). Currently, there is no specific standard for *wafer durability index* (WDI) and it is still guided by the *pellet durability index* (PDI) standard. The standard of good PDI for storage and transportation is above 90% (Triyanto et al., 2013). Jaelani et al. (2016) stated that the minimum specification standard for pellet *durability index* is 80%.

2. Storage Time

Complete wafers based on mung bean sprout husk waste were stored in plastic packaging *(standing pouch)* which is observed for a period of one month to determine the best shelf life until fungal growth occurs. The results of the observation during storage can be seen in Table 5.

Table 5. Storage time of complete wafer

Treatment	Shelf Life (Weeks)		
	0	2	4
P0	Non-moldy	Non-moldy	Non-moldy
P1	Non-moldy	Non-moldy	Non-moldy
P2	Non-moldy	Non-moldy	Non-moldy
P3	Non-moldy	Non-moldy	Non-moldy

Description: P0: Ration + without the addition of mung bean sprout husk, P1: Ration + 10% mung bean sprout husk, P2: Ration + 20% mung bean sprout husk, P3: Ration + 30% mung bean sprout husk.

According to research by Silaban et al. (2020), wafers packaged with plastic show better physical performance than any packaged in other materials. Observation of the storage time of 0 weeks, 2 weeks and 4 weeks in Table 5 shows that there was no fungal growth in wafers. According to Imbar et al. (2023) wafers with a moisture content of > 14% can be at risk of fungal growth during the storage. A low moisture content on the wafer will be better with a longer storage times. The storage period of 6 weeks is only able to maintain the color of the wafer but is not able to maintain the texture, odor, density, moisture content and mold.

Simamora et al.'s (2022) research for 6 weeks of storage showed that the physical quality of wafer was good. Storage at room temperature did not cause any significant changes with no fungi found in all the formulas tested. However, the texture decreases due to increased moisture due to air entering through the pores of the plastic packaging used (Rachmawati, 2023) and causing cracks in the wafers (Salam, 2017). The absence of fungal growth across supplementation levels (0–30%) for up to four weeks in standing-pouch plastic indicates that wafers can be safely staged at room temperature for short-term on-farm use. This aligns with reports that plastic packaging preserves physical integrity better than alternative materials, while also echoing cautions that moisture pickup over time is the main driver of quality loss (texture softening) rather than immediate mold spoilage. In practice, farmers can plan monthly production cycles and apply FIFO rotation with a conservative shelf-life claim of ≥4 weeks under intact seals and ambient storage.

CONCLUSION

Complete wafers based on mung bean sprout husk waste showed the best results in rations with the addition of 30% mung bean sprout husk waste to the physical quality of density and water absorption. Storage time to 4 weeks weeks in standing-pouch plastic indicates that wafers can be safely staged at room temperature for short-term on-farm use.

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