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Research Article

Tapioca Starch is used as An Adhesive in "Complete Feed Wafers" Based on Fermented Sugarcane Tops and Tithonia for the Physical Properties of Wafers

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ABSTRACT

This study aims to determine how long fermented sugarcane tops (*Saccharum officinarum L.*) and tithonia (*Tithonia diversifolia*) wafers can be stored. This study used a completely randomized design with four treatments and four replicates. The treatments consisted of T1 (15 days storage duration), T2 (30 days storage duration), T3 (45 days storage duration), and T4 (60 days storage duration). The variables measured were color, aroma, texture, density, water absorption, and total fungal colonies. The data obtained from the study were analyzed using the variance analysis method, and the differences in the means of each treatment were further tested using the Duncan Multiple Range Test. The results of the analysis showed that shelf life had a very significant effect ($P<0.01$) on color, aroma, texture, water absorption, and total fungal colonies but gave no significant effect ($P>0.05$) on wafer density. The average results of color (3.3 - 3.7), aroma (3.2 - 3.6), texture (3.1 - 3.6), density (0.60 - 0.71 g/cm3), water absorption (72.8 - 85.3%) and total fungal colonies (1.10 x 10^2 CFU/ml to 3.03 x 10^2 CFU/ml). The results of this study indicate that 60 days of storage on sugarcane tops and tithonia wafers can still maintain the physical quality of wafers in terms of color, aroma, texture, water absorption, and total fungal colonies.

Keywords: physical quality, storage duration, sugarcane shoots, tithonia, wafers

INTRODUCTION

Forage availability as the primary feed for ruminant livestock is increasingly declining, influenced by seasonal changes and shrinking land due to development sectors. Therefore, it is necessary to develop alternative feeds that can be used for ruminant livestock. One alternative feed that can be utilized is sugarcane tops (*Saccharum officinarum L*). According to Ditjennak (2012), sugarcane tops are sugarcane plantation waste, comprising up to 30% of the total weight of sugarcane remaining after harvest. West Sumatra has sugarcane plantations covering an area of approximately 7,900 hectares, with sugarcane production reaching around 11,079,000 tons per year (BPS, 2018). Lamid (2016) stated that the nutritional content of sugarcane tops includes dry matter at 39.9%, crude protein at 7.4%, crude fat at 2.90%, crude fiber at 42.30%, and ash at 7.42%. Sugarcane tops also have a Nitrogen-Free Extract (NFE) content of 42.54%.

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Sugarcane tops can be used as livestock feed and serve as a good source of carbohydrates (Ikhlas *et al*., 2023; Pazla *et al*., 2023).

In addition to using sugarcane tops as an energy source in feed, it is also necessary to balance the feed with ingredients containing high protein to meet livestock nutritional needs. Tithonia (*Tithonia diversifolia*) is a plant with high potential for use as ruminant livestock feed due to its high protein content (Arief *et al*., 2020; Pazla *et al*., 2021a; Pazla *et al*., 2021b; Jamarun *et al*., 2023; Jamarun *et al*., 2024; Pazla *et al*., 2024). According to research by Pazla *et al*. (2022), tithonia can serve as an alternative protein source because of its high nutritional content, including 25.57% dry matter, 84.01% organic matter, 22.98% crude protein, 18.17% crude fiber, and 4.57% lignin. Hakim and Agustian (2012) explained that in West Sumatra, this plant can produce up to 30 tons of fresh material or 6 tons of dry matter annually. Planting as a hedgerow can yield approximately 27 kg of dry weight from three harvests annually. However, tithonia has not been widely utilized as feed for ruminant livestock by farmers or breeders.

Feed processing technology can be applied in wafers to ensure the continued usefulness of sugarcane tops and tithonia for livestock and maintain feed availability. Wafers involve mixing and compacting various feed ingredients to produce a feed product with complete nutritional content. Wafers, square or cube-shaped, are designed to facilitate handling and feeding livestock while being efficient in storage due to their dense and compact form. The principle of wafer production includes mixing, compacting, and heating (Ikhlas *et al*., 2024). Processing feed into wafers also prevents de-mixing or the separation of feed components, ensuring feed intake aligns with livestock needs. It also simplifies the control, monitoring, and regulation of livestock feed intake, guarantees consistent and reliable nutrient content, and reduces dust and respiratory issues in livestock (Sabri *et al*., 2017)

To produce high-quality feed wafers that are dense, compact, and nutritionally rich, one of the key factors is the use of a binding agent. A primary requirement for a material to serve as a binding agent is its high starch content, such as amylose and amylopectin, which undergo a gelatinization process when heated, binding other ingredients together. Tapioca flour contains 18.0% amylose and 60.15% amylopectin, which are crucial for gelatinization, making it an effective binder in wafer production.

In livestock farming, feed is a determining factor for the success of an enterprise, and its availability is significantly influenced by time, necessitating proper storage. Storage is an activity undertaken to delay the deterioration of an item before its use without altering its form. According to Yoresta (2020), in a study, complete ration wafers made from cassava waste stored for 60 days could maintain good physical quality, as observed in texture, aroma, color, water absorption, density, and mold presence.

MATERIAL AND METHODS

Materials and Equipment Research

The equipment used in this study includes a chopper machine, blender, wafer mold machine, vacuum plastic, vacuum sealer, glass plastic, basins, mixing spoons, sacks, analytical scales, test tubes, Petri dishes, aluminum foil, tissues, beakers, desiccator, oven, Erlenmeyer flask, Petri dishes, test tubes, trays, scissors, rulers, markers, clamps, stove, stopwatch, filter glasses, volumetric flasks, vacuum apparatus, autoclave, and various other laboratory instruments.

The materials used in the study for making wafers consist of sugarcane tops obtained from sugarcane plantations in Matur, Puncak Lawang, and tithonia collected from the Padang Panjang area. Other materials for the ration formula include fine bran, tofu pulp, ground corn, premix,

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salt, minerals, molasses, and tapioca flour as a binder for the sugarcane tops and tithonia wafers. Additional materials required for testing total fungal colonies include PDA (Potato Dextrose Agar), distilled water, physiological solutions, and other necessary materials needed during the research process.

Research Design

This study utilized a Completely Randomized Design with four treatments and four replications. The treatments were as follows: T1: 15 days of storage, T2: 30 days of storage, T3: 45 days of storage, and T4: 60 days of storage. The variables measured were color, aroma, texture, density, water absorption, and total fungal colonies.

Table 1. Nutrient contents

Nutrient content	Feed ingredient					
	Fermented Sugarcane tops	Tithonia diversifolia	Tapioca starch	Bran	Corn	Tofu dregs
Dry matter	62.30	24.89	86.13	87.5	85.55	85.91
Organic matter	88.43	85.72	99.94	89.44	95.87	94.4
Crude protein	1.34	2.06	1.9	6.28	6	2.8
NFE	8.36	21.88	4.4	11.09	9.82	19.26
TDN	11.57	14.28	0.06	10.56	3.09	5.6
ADF	37.98	18.72	4.6	9.23	9.61	16.8
Cellulose	40.75	43.06	89.04	62.84	71.48	55.54
Hemicellulose	48.96	63.22	82	74.87	77.69	70.22
Lignin	80.87	60.72	2.1	48.11	58.62	39.28

TDN = Total Digestibility Nitrogen; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber, NFE = Nitrogen Free Extract

Table 2. Ration composition

Feed ingredient	Ration composition
Tapioca starch	10
Fermented sugarcane tops	30
Tithonia diversifolia	30
Bran	14
Corn	8
Tofu Dregs	6
Molasses	1.5
Minerals	0.5

Table 3. Ration nutrient content

Nutrient content	Nutritional content
Dry matter	88.93
Organic matter	89.43
Crude fat	3.06
Crude protein	12.84
Ash	9.46
Crude Fiber	20.48

Nutrient content	Nutritional content
NFE	53.52
TDN	63.59

Table 4. Wafer criteria score

Criteria	Karakteristik	Score	Description
Color	Dark brown/black	3-3.9	Very good
	Light brown	2-2.9	Good
	Brown with white specks	1-1.9	Adequate
Aroma	Distinct wafer smell	3-3.9	Very good
	Odorless	2-2.9	Good
	Rancid	1-1.9	Adequate
Texture	Coarse, dense texture (not easily broken) and not slimy	3-3.9	Very good
	Rough texture, easy to break, and not slimy	2-2.9	Good
	Wet texture, easy to break, and slimy	1-1.9	Adequate

Water absorption (Trisyulianti *et al*., 2003)

Research Procedure

Producing sugarcane tops and tithonia wafers as ruminant livestock feed involved the addition of tapioca as the best binder based on previous testing. The production process included four treatments with different storage durations, namely 15 days, 30 days, 45 days, and 60 days, and was carried out with four replications. The first step was preparing all tools and materials and weighing the ingredients according to the predetermined ration formulation. The ingredients were gradually mixed in a container, starting from smaller-sized materials to larger ones, to ensure homogeneity. Liquid ingredients such as molasses were heated with water until boiling to dissolve them, then poured into the feed mixture and stirred until evenly distributed, resulting in gelatinization. The homogeneous mixture was placed into cube-shaped molds and compacted to form dense and compact wafers. Afterward, the wafers were dried in an oven at 120^{o}C for 30 minutes and then cooled at room temperature. The dried wafers were packed in vacuum-sealed plastic to remove air inside the packaging, aiming to extend their shelf life. The completed wafers were then tested based on the predetermined research parameters.

Data Analysis

Analysis of data was performed by analysis for variance (ANOVA) on IBM SPSS statistics version 26.0 (IBM Corp, NY, USA). Duncan Multiple Range Test (DMRT) was performed as a further test.

RESULTS AND DISCUSSION

Color of Wafer

Table 5. Average physical quality of Sugarcane Top and Tithonia Wafer

Treatment	Color	Aroma	Texture	Density (g/cm^3)	Water absorption (%)
T1	3.3^{c}	3.2^{c}	3.2^{c}	0.60	85.3^{a}
T2	3.4^{c}	3.3^{c}	3.3^{c}	0.63	81.8^{b}
T3	3.5^{b}	3.5^{b}	3.5^{b}	0.66	74.8^{c}

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Treatment	Color	Aroma	Texture	Density (g/cm^3)	Water absorption (%)
T4	3.7^a	3.6^a	3.6^a	0.71	72.8^c
SE	0.07	0.06	0.07	0.08	1.48

The data in Table 5 shows that the color score of the wafers ranges from 3.3 to 3.7. Based on Table 5, there is an increase in the color score as the storage duration increases. Several factors must be considered to understand the impact of storage duration on the Wafer's color. the aroma scores range from 3.2 to 3.6. The aroma in wafers is an important indicator that can signal the presence or absence of damage, which can be observed through changes in the aroma. This helps evaluate the quality of the livestock feed wafers before and after the storage period**.** The texture scores range from 3.1 to 3.6. The high texture score for T4, with a 60-day storage period, is suspected to be caused by an increase in wafer density as the storage duration increases. This results in a lower ability of the Wafer to absorb water. Consequently, the Wafer's moisture content decreases with longer storage time, which ultimately increases the Wafer's texture density. According to Abdullah *et al*. (2016), the density of the Wafer is influenced by its ability to absorb water; the lower the water absorption capacity, the denser the texture will be. The density values range from 0.62 to 0.70 g/cm^3. The highest average density of the wafers is observed in treatment T4 with a 60-day storage period (0.70 g/cm^3), followed by treatment P3 with a 45-day storage period (0.67 g/cm^3), P2 with a 30-day storage period (0.64 g/cm^3), and P1 with a 15-day storage period (0.62 g/cm^3). Storage duration does not significantly affect (P>0.05) the density of the sugarcane tops and tithonia wafers. The variation in density is attributed to the uneven distribution of materials during the molding process, and the different particle sizes of the materials also affect the density value (Su *et al*., 2022).

The brown color of the sugarcane tops and tithonia wafers is caused by several factors, including the raw materials used in making the wafers, the effect of temperature, and the duration of heating. The raw materials that contribute to the Wafer's dark brown or blackish-brown color are molasses and palm kernel meal, which both have dark colors, as well as the drying process of the raw ingredients. The change to a darker brown color also occurs due to the relatively high heating process, and the sugarcane tops and tithonia ingredients are similar. Yoresta (2020) stated that the color change during heating makes the materials appear darker brown. The high color score for T4, with a 60-day storage period, is due to the absorption of moisture from the surrounding environment during storage, which causes the wafer surface to darken further.

The aroma of sugarcane tops and tithonia wafers can be influenced by the duration of storage. A pleasing aroma in feed wafers is a pleasant fragrance, as fresh aroma can enhance livestock consumption. Several factors affecting the aroma of feed wafers include the type of raw materials used, the storage duration, and the nutrient content of the wafers (Adriani *et al*, 2021). Aroma changes in wafers can be affected by microbial activity, especially in feed with high moisture content (Ikhlas *et al*., 2024). Unwanted aroma changes are often caused by microorganisms that produce unpleasant odors (off odors), such as bacteria, fungi, and natural microflora. Thus, the aroma quality of the wafers begins to decline from its characteristic scent during storage, although it can still be maintained for up to 60 days.

Tiefenbacher (2017) also explained that high oven temperatures contribute to a good wafer texture. Higher temperatures and longer durations during the oven process can produce optimal wafer texture. Additionally, factors affecting the hardness of the texture include moisture

content, carbohydrate (starch) content, and density. The higher the moisture content, starch content, and density of the complete ration wafer, the greater the hardness of its texture. The hardness of the wafer texture increases as the carbohydrate content in the Wafer's feed ration rises.

According to Serrano *et al* (2011), the main factors influencing density are the raw material type and the material's compaction in the wafer mold. Roffi *et al* (2013) states that a good density is around 0.69 g/cm^3. Daud *et al*. (2013) suggest that the desired density range is 0.5 - 0.6 g/cm^3. The higher the density value, the better it is for storage, as ess water is absorbed during storage. High wafer density physically facilitates handling, both in storage and during transportation, and it is expected to last longer in storage due to its compact and firm physical form.

The water absorption capacity of the Wafer refers to its ability to bind or absorb water or moisture from the surrounding environment. The water absorption value is inversely proportional to the density value; the higher the density, the lower the water absorption capacity (Syahrir *et al*., 2017).

The high water absorption capacity observed during the 15-day storage period is due to the condition of the Wafer, which is vacuum-sealed in plastic and has a still-good texture. As a result, the Wafer can absorb water effectively. This is supported by a study by Islami *et al*. (2018), which suggests that the high water absorption at a 2-week storage period is because the Wafer's texture density is still in good condition, allowing it to absorb water effectively. Water absorption is also influenced by the high fiber content of the raw materials used in the Wafer (sugarcane tops and tithonia). This is because the more fiber used, the weaker the particle binding of the feed material, leading to an increased water absorption capacity.

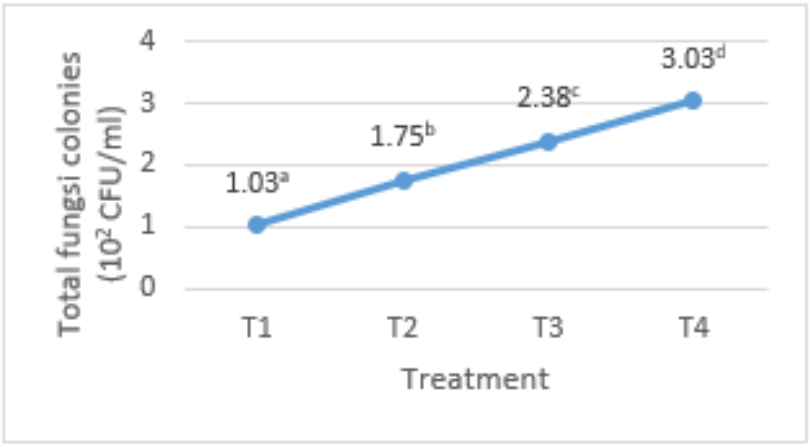


Figure 1. Total fungsi colonies (10^2 CFU/ml)

The data in Figure 1 shows that the total fungal colony ranges from 1.03 to 3.03 x 10^2 CFU/ml, with an increase in total fungal colonies as the storage period lengthens. The low total fungal colonies in treatment T1 (15-day storage) at 1.03 x 10^2 CFU/ml are due to the proper storage conditions and the contamination-free production process, which reduces the acceleration of fungal growth. The maximum limit for fungal contamination in mixed feed is 500 colonies per gram. At the same time, the Indonesian National Standard (SNI, 2017) sets the maximum limit for fungal contamination in concentrated feed at 1000 colonies per gram.

The highest fungal growth on the sugarcane top and tithonia wafers was observed in T4 with a 60-day storage period. This is due to environmental factors such as humidity and temperature

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where the wafers were stored. The average storage temperature of the sugarcane top and tithonia wafers during the study ranged from 26-28^{o}C, which supports the growth of microorganisms like bacteria, molds, and fungi during the storage of the animal feed wafers (Yoresta, 2020). According to Wang *et al*., (2013), most molds require optimal temperatures for growth. Furthermore, storage duration can influence the moisture content of the wafers, where humidity and environmental temperature play key roles in promoting fungal growth, thus accelerating the degradation of the animal feed wafers.

CONCLUSION

Based on the results of the study, it can be concluded that the 60-day storage period for sugarcane top and tithonia wafers still maintains their physical quality in terms of color with a score of 3.7 (dark brown), aroma with a score of 3.6 (distinct wafer smell), texture with a score of 3.6 (having a coarse, dense texture that is not easily broken and not slimy), density (0.71 g/cm^3), water absorption (72.88%), and total fungal colony (3.03 x 10^2 CFU/ml).

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