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PHYSICAL PROPERTIES OF SUGARCANE (*Saccharum officinarum*) AND TITHONIA (*Tithonia diversifolia*) SHOOT-BASED WAFERS WITH DIFFERENT ADHESIVE TYPES

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ABSTRACT: Wafers (wafer-feed) are an effective processing technology and are expected to maintain the continuous availability of animal feed during the dry season. The purpose of this study was to determine the best type of adhesive on the physical quality of sugarcane tops and Tithonia based wafers. This study used the Split Split Plot Design (SSPD). The main plot as factor A was the type of adhesive, consisting of: Tapioca flour (A1), Pathi flour (A2), Gaplek flour (A3), Karagenan flour (A4), palm sugar (A5). The subplots as Factor B are temperature which consists of: 100°C (B1), 110°C (B2), and 120°C (B3), while the sub-plots as factor C are oven time consisting of: 10 minutes (C1), 15 minutes (C2), and 20 minutes (C3). The forage used was Sugarcane tops (*Saccharum officinarum*) and Tithonia (*Tithonia diversifolia*) in the ratio of 60:40. The best adhesive in making sugarcane tops and Tithonia based wafers is tapioca flour with a temperature of 120°C for 20 minutes, with physical properties such as colour, aroma, and excellent texture with a range (3.73, 3.70, and 3.63), density with a value of 5.68 g/cm^3, and water binding capacity with a value of 104.22%. From the research it can be concluded that there are interactions on the physical properties of wafers (colour, aroma, and smell), density and water binding capacity. For further research, the best wafers obtained were continued to the in vitro digestibility stage to see the digestibility of wafers as ruminant feed.

Keywords: Binding, Physical qualities, Sugarcane shoots, *Tithonia diversifolia*, Wafer

INTRODUCTION

Feed is one of the factors that greatly affect the success of livestock business both in terms of quality and quantity. Feeding that has good quality and in accordance with the needs of livestock will produce livestock that have high productivity. The availability of forage is very abundant during the rainy season, while it is very limited during the dry season, so it is necessary to find alternative feed to meet the needs of forage for livestock.

Alternatives that can be used to meet the needs of forage for ruminants are by utilising sugarcane tops and tithonia. One hectare of sugarcane plantation will produce 110 tonnes/year consisting of 72 tonnes of bagasse and 38 tonnes of sugarcane tops (Conrad and Prasetyaning, 2014). The amount of sugarcane production must be utilised as a forage source of energy for ruminants (Pazla et al., 2021; Pazla et al., 2023; Arief et al., 2023).

Explained that sugarcane tops can be used as a source of fibre feed because it has high crude fibre and its availability is large and rarely used by humans. The content of sugarcane tops is dry matter 60.62%, organic matter 87.81%, crude protein 8.53%, crude fat 1.64%, crude fiber 38.72%, cellulose 29.08%, and Total digestible Nutrient (TDN) 57.30%. Therefore, sugarcane tops have the potential to be used as an energy source animal feed for ruminants (Pazla et al., 2022).

Tithonia plants harvested six times a year can produce dry biomass production of 4.10 -10.20 tonnes / ha or fresh production of 24.00 - 46.80 tonnes / ha / year (Jama et al., 2000). Tithonia has not been widely utilized by the community because it is often regarded as a weed that cannot be used as animal feed, even though tithonia can be a ruminant feed because it contains quite good nutrients (Pazla et al., 2023b; Jamarun et al., 2023). The nutritional content of tithonia is 25.57% dry matter, 84.01% organic matter, 22.98% crude protein, 18.17% crude fibre, 61.12 neutral detergent fiber (NDF), 40.15% acid detergent fiber (ADF), 34.59% cellulose, 20.97% hemicellulose, and 4.57 lignin (Pazla et al., 2021b). Hence, tithonia has the potential so that it can be used and developed as a protein source feed for ruminants.

To increase shelf life, it is necessary to have a touch of technology to reduce water content, one of which is wafer feed processing. Wafer is one of the effective feed processing technologies and is expected to maintain the continuity of animal feed, especially in the dry season and has a dense and compact square physical form that greatly facilitates storage and handling. The advantages of processing feed into wafers include increasing density, reducing storage space,

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reducing transportation costs, making it easier to control, monitor and regulate livestock feed intake, consistent and guaranteed nutrient content, reducing dust and respiratory problems in livestock (Kaliyan and Morey, 2009). The physical quality of wafers is strongly supported by adhesives. Adhesives are additional ingredients that are deliberately added to the formulation of feed ingredients to unite all the raw materials used (Adelina et al., 2023). Some natural ingredients that have been used for wafers include wheat flour, corn flour, rice flour, onggok, and palm sugar (Retnani et al., 2023). This study aims to determine the physical quality of colour, aroma, texture, density, water binding capacity and various types of adhesives used to make sugarcane tops and tithonia-based wafers.

MATERIALS AND METHODS

Materials

The main materials are sugarcane tops (*Saccaharum officinarum*) and tithonia (*tithonia diversifolia*) in a ratio of 60:40. Sugarcane tops are taken in the Puncak Lawang, Agam area and Tithonia is taken in Padang Panjang, both materials were dried and mashed. Types of adhesives are: tapioca flour, pathi flour, karagenan, flour, cassava flour, palm sugar were obtained at belimbing traditional market.

Methods

This research method uses a complete randomized design factorial pattern with 3 factors. Factor A is the application of various types of adhesives consisting of: Tapioca flour (A1), Patin flour (A2), cassava flour (A3), Karagenan flour (A4), palm sugar (A5). Factor B drying temperature in the oven consisting of: 100°C (B1), 110°C (B2), 120°C (B3), while as factor C is the length of drying time in the oven consisting of: 10 minutes (C1), 15 minutes (C2), and 20 minutes (C3). Each treatment was repeated three times.

Research procedure

Tools used for the manufacture of wafers are mier, grinder machine, wafer felting machine, wafer mould, analytical scales, oven and vernier. The combination of sugarcane tops and tithonia is added to various types of adhesives according to the treatment of factors A, B, and C. The wafers are ready to be analyzed.

Parameters measured

Determination of texture, colour and aroma

Observations of physical properties were made by scoring each wafer criterion, which can be seen in Table 2.

Water absorption (Trisyulianti et al., 2003)

Water absorption was obtained from measuring the weight of wafers before and after soaking with water for 5 minutes. The percentage of water absorption was obtained by the formula:

DSA (%) = (BA-BB)/BA x 100%

When. DSA = water absorption (%); BA = Initial Weight (g); BB = Final Weight (g)

Density measurements (Trisyulianti et al., 2003)

Density is an important factor in the physical properties of wafers as a guide to obtain an overview of the desired wafer strength. Wafer density value can be calculated by the formula

K = W/(P x T x L)

When. K = Density (g cm^{-3}); W = Weight of Test Sample (g); P = Length of Test Sample (cm); L = Width of Test Sample (cm); T = Thickness of Test Sample (cm).

Table 1 - Chemical composition of the feed ingredients making up the treatment ration (%DM)

Nutritional Content (%) \ Feed Ingredients	*Saccaharum officinarum*	*Tithonia diversifolia*
Dry matter	60.02	81.79
Organic matter	86.60	83.49
Crude protein	7.88	21.85
Crude fat	1.50	3.21
Crude fiber	40.83	21.21
NFE	36.39	37.23
ADF	55.80	39.80
NDF	86.83	60.31
Cellulose	33.84	25.83
Hemicellulose	31.03	20.51

NFE= Nitrogen Free Extract, ADF = acid detergent fiber, NDF = neutral detergent fiber

Table 2 – Wafer characteristics assessment criteria

Criteria	Characteristic	Score	Description
Aroma	Smells	3 - 3.9	Very good
	Odourless	2 - 2.9	Good
	Rancid	1 - 1.9	Fair
Colour	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

Source; (Solihin et al., 2015)

Statistical analysis

This study used Split split plot design (SPPD). Data were analysed using Analysis of Variance (ANOVA). Significant differences among treatments were further tested using Tukey's test. All procedures were performed using SPSS 20 statistical package software. The results were analysed using generalised linear models method with IBM SPSS Statistics 26.0 version (IBM Corp., NY, USA).

RESULT

Physical properties of wafers

Wafer colour

The average colour score of sugarcane tops and tithonia-based wafers using several types of adhesives according to the treatment can be seen in Table 3. Data of table 3 shows that the manufacture of sugarcane tops and tithonia-based wafers with different types of adhesives has a very significant effect ($P<0.01$) on the colour of the wafers produced, on the colour of water there is an interaction ($P<0.01$) between the type of adhesive, temperature and length of oven time.

Wafer aroma

Wafer aroma is an indicator that can be used to determine the presence or absence of damage through changes in aroma that occur in wafers, so as to determine the quality of wafers. The average aroma score of sugarcane tops and tithonia-based wafers using several types of adhesives according to the treatment can be seen in Table 4. Data of table 4 shows that the manufacture of sugarcane tops and tithonia-based wafers with different types of adhesives has a very significant effect ($P<0.01$) on the aroma of wafers produced, on the aroma of water there is an interaction ($P<0.01$) between the type of adhesive, temperature and length of oven time.

Wafer texture

The average texture score of sugarcane tops and tithonia-based wafers using several types of adhesives according to the treatment can be seen in Table 5. Data of table 5 shows that the manufacture of wafers based on sugarcane tops and tithonia with different types of adhesive has a very significant effect ($P<0.01$) on the texture of the wafers produced, on the texture of water there is an interaction ($P<0.01$) between the type of adhesive, temperature and length of oven time.

Wafer density

The density value indicates the density of the wafer feed and also determines the physical shape of the wafer feed produced. The average density of sugarcane tops and tithonia-based wafers using several types of adhesives according to the treatment can be seen in Table 6. The data of table 6 shows that the manufacture of sugarcane tops and tithonia-based wafers with different types of adhesives has a very significant effect ($P<0.01$) on the density of wafers produced, on the density of wafers there is an interaction ($P<0.01$) between the type of adhesive, temperature and length of oven time. The highest density was found in the type of tapioca starch adhesive with a temperature of 120^{o}C which was oven for 20 minutes with a value of 5.68 g/cm-3. And the lowest was found in the type of keriginan flour adhesive with a temperature of 100^{o}C which was oven for 20 minutes.

Water absorption

The average water absorption of sugarcane tops and tithonia-based wafers using several types of adhesives according to the treatment can be seen in Table 7. Data of table 7 shows that the manufacture of sugarcane tops and tithonia-based wafers with different types of adhesives has a very significant effect ($P<0.01$) on the water absorption of wafers produced, on the water absorption of wafers there is an interaction ($P<0.01$) between the type of adhesive, temperature and length of oven time. The lowest water absorption was found in the type of tapioca flour adhesive with a temperature of 120^{o}C which was oven for 20 minutes with a value of 104.22%. The highest was found in the type of pathi flour adhesive with a temperature of 100^{o}C which was oven for 10 minutes with a value of 119.58%.

Table 3 - Average colour values of sugarcane tops and fermented tithonia-based wafers

Factor A	Factor B	Factor C		
		C1	C2	C3
A1	B1	3.23^{bcdefg} ± 0.35	2.70^{abc} ± 0.26	2.97^{abcde} ± 0.26
	B2	3.00^{abcde} ± 0.20	3.03^{abcdef} ± 0.25	3.17^{abcdefg} ± 0.21
	B3	3.07^{abcdefg} ± 0.15	2.70^{abc} ± 0.10	3.73^{g} ± 0.15
A2	B1	2.57^{a} ± 0.25	2.60^{ab} ± 0.20	2.70^{abc} ± 0.36
	B2	2.77^{abc} ± 0.15	3.13^{abcdefg} ± 0.15	2.83^{abc} ± 0.15
	B3	3.13^{abcdefg} ± 0.21	3.17^{abcdefg} ± 0.25	3.03^{abcdef} ± 0.21
A3	B1	3.00^{abcde} ± 0.36	3.17 ^{abcdefg} ± 0.15	2.57^{a} ± 0.31
	B2	2.90^{abcd} ± 0.10	2.80^{abc} ± 0.10	3.00^{abcde} ± 0.26
	B3	3.20^{abcdefg} ± 0.26	3.03^{abcdef} ± 0.15	2.60^{ab} ± 0.10
A4	B1	3.03^{abcdef} ± 0.15	3.20^{abcdefg} ± 0.10	3.07 ^{abcdefg} ± 0.15
	B2	3.30^{cdefg} ± 0.26	3.30^{cdefg} ± 0.20	3.07 ^{abcdefg} ± 0.15
	B3	3.57^{efg} ± 0.15	3.50^{defg} ± 0.10	3.67^{fg} ± 0.06
A5	B1	2.93^{abcde} ± 0.06	2.70^{abc} ± 0.20	2.83^{abc} ± 0.21
	B2	3.00^{abcde} ± 0.17	2.77^{abc} ± 0.06	2.30^{abcde} ± 0.35
	B3	3.03^{abcdef} ± 0.12	2.97^{abcde} ± 0.15	2.27^{abcdef} ± 0.15

Note: Statistical further test using generalized linear models method, Different superscripts in the columns above indicate significant differences (P<0.01), ± standard deviation. Factor A : A1: tapioca flour; A2: patin flour; A3: cassava flour; A4: karagenan flour; A5: palm sugar; and Factor B : B1: 100^{o}C; B2: 110^{o}C; C3: 120^{o}C.

Table 4 - Mean value of aroma of sugarcane tops and tithonia based wafers

Factor A	Factor B	Factor C		
		C1	C2	C3
A1	B1	3.40^{e} ± 0.35	2.50^{a} ± 0.26	3.03^{bcde} ± 0.26
	B2	3.03^{bcde} ± 0.20	3.17^{cdf} ± 0.25	3.27^{ef} ± 0.21
	B3	3.23^{cdf} ± 0.15	2.67^{abcd} ± 0.10	3.70^{f} ± 0.15
A2	B1	2.33^{a} ± 0.91	2.50^{ab} ±0.25	2.33^{a} ± 0.20
	B2	2.50^{ab} ± 0.15	2.33^{a} ± 0.15	2.50^{ab} ± 0.25
	B3	2.50^{ab} ± 0.21	2.33^{a} ± 0.25	2.50^{ab} ± 0.21
A3	B1	2.57^{ab} ± 0.35	2.40^{a} ± 0.15	2.50^{ab} ± 0.31
	B2	2.43^{ab} ± 0.10	2.50^{ab} ± 0.10	2.43^{ab} ± 0.26
	B3	2.60^{ab} ± 0.26	2.37^{a} ± 0.15	2.43^{ab} ± 0.10
A4	B1	2.70^{abcd} ± 0.15	3.37^{ef} ± 0.10	3.43^{ef} ± 0.15
	B2	3.63^{f} ± 0.26	3.57^{ef} ± 0.20	3.53^{ef} ± 0.15
	B3	3.53^{ef} ± 0.15	3.57^{ef} ± 0.10	3.70^{f} ± 0.06
A5	B1	2.50^{ab} ± 0.06	2.53^{ab} ± 0.20	2.33^{a} ±0.21
	B2	2.67^{abcd}± 0.17	2.37^{a} ± 0.06	2.30^{a} ± 0.35
	B3	2.50^{ab} ± 0.12	2.50^{ab} ± 0.15	2.27^{a} ± 0.15

Note: statistical further test using generalized linear models method, Different superscripts in the columns above indicate significant differences (P<0.01), ± standard deviation. Factor A : A1: tapioca flour; A2: patin flour; A3: cassava flour; A4: karagenan flour; A5: palm sugar; and Factor B : B1: 100^{o}C; B2: 110^{o}C; C3: 120^{o}C.

Table 5 - Mean Tekstur value of sugarcane tops and tithonia based wafers

Factor A	Factor B	Factor C		
		C1	C2	C3
A1	B1	3.53^{ef} ± 0.15	3.30^{cdef} ± 0.20	3.00^{abc} ± 0.20
	B2	3.50^{def} ± 0.10	3.00^{abc} ± 0.10	3.10^{abcde} ± 0.10
	B3	3.00^{abc} ± 0.17	3.00^{abc} ± 0.10	3.63^{f} ±0.06
A2	B1	2.63^{a} ± 0.06	2.90^{abc} ± 0.20	2.80^{ab} ± 0.10
	B2	2.80^{ab} ± 0.17	3.03^{abcd} ± 0.21	3.00^{abc} ± 0.10
	B3	3.00^{abc} ± 0.20	3.07^{abcde} ± 0.15	2.87^{abc} ± 0.06
A3	B1	2.97^{abc} ± 0.06	3.23^{bcdef} ± 0.06	3.17^{bcdef} ± 0.12
	B2	3.17^{bcdef} ± 0.15	3.00^{abc} ± 0.10	3.00^{abc} ± 0.20
	B3	3.30^{cdef} ± 0.10	3.27^{bcdef} ± 0.12	3.10^{abcde} ± 0.10
A4	B1	3.03^{abcd} ± 0.06	3.03^{abcd} ± 0.12	3.07^{abcde} ± 0.21
	B2	3.20^{bcdef} ± 0.10	3.30^{cdef} ± 0.10	3.23^{bcdef} ± 0.15
	B3	3.23^{bcdef} ± 0.25	3.30^{cdef} ± 0.20	3.60^{f} ± 0.10
A5	B1	3.03^{abcd} ± 0.12	3.17^{bcdef} ± 0.06	3.27^{bcdef} ± 0.06
	B2	3.03^{abcd} ± 0.32	3.17^{bcdef} ± 0.06	3.03^{abcd} ± 0.06
	B3	3.07^{abcde} ± 0.15	3.17^{bcdef} ± 0.15	3.23^{bcdef} ± 0.06

Note: statistical further test using generalized linear models method, Different superscripts in the columns above indicate significant differences (P<0.01), ± standard deviation. Factor A : A1: tapioca flour; A2: patin flour; A3: cassava flour; A4: karagenan flour; A5: palm sugar; and Factor B : B1: 100^{o}C; B2: 110^{o}C; C3: 120^{o}C.

Table 6 - Average values of sugarcane tops and tithonia based wafer density (g/cm^3)

Factor A	Factor B	Factor C		
		C1	C2	C3
A1	B1	$4.29^{abcd} \pm 0.09$	$5.36^{mno} \pm 0.06$	$5.20^{ijklmno} \pm 0.20$
	B2	$5.43^{no} \pm 0.04$	$4.97^{ghijklmno} \pm 0.08$	$5.19^{ijklmno} \pm 0.9$
	B3	$5.38^{mno} \pm 0.12$	$5.50^{o} \pm 0.07$	$5.68^{q} \pm 0.04$
A2	B1	$5.28^{klmno} \pm 0.04$	$4.99^{ghijklmno} \pm 0.04$	$4.74^{cdfghij} \pm 0.10$
	B2	$4.81^{dfghijkl} \pm 0.02$	$4.90^{fghijklmn} \pm 0.02$	$4.62^{bcdfgh} \pm 0.05$
	B3	$5.10^{hijklmno} \pm 0.05$	$5.19^{ijklmno} \pm 0.03$	$5.21^{jklmno} \pm 0.03$
A3	B1	$4.35^{bcd} \pm 0.04$	$4.41^{bcdf} \pm 0.03$	$3.79^{a} \pm 0.05$
	B2	$4.22^{abc} \pm 0.04$	$4.35^{bcd} \pm 0.05$	$4.73^{bcdfghij} \pm 0.03$
	B3	$4.90^{fghijklmn} \pm 0.02$	$4.36^{bcd} \pm 0.04$	$5.05^{ghijklmno} \pm 0.05$
A4	B1	$4.42^{bcdf} \pm 0.03$	$4.67^{bcdfghi} \pm 0.03$	$5.25^{jklmno} \pm 0.04$
	B2	$5.22^{jklmno} \pm 0.04$	$5.00^{ghijklmno} \pm 0.02$	$5.26^{jklmno} \pm 0.04$
	B3	$5.30^{lmno} \pm 0.03$	$5.32^{lmno} \pm 0.02$	$5.62^{p} \pm 0.02$
A5	B1	$4.55^{bcdfg} \pm 0.04$	$4.76^{dfghijk} \pm 0.04$	$4.22^{abc} \pm 0.03$
	B2	$4.21^{abc} \pm 0.06$	$4.20^{ab} \pm 0.02$	$4.60^{bcdfgh} \pm 0.02$
	B3	$4.48^{bcdf} \pm 0.05$	$4.91^{fghijklmn} \pm 0.04$	$4.89^{fghijklm} \pm 0.03$

Note: statistical further test using generalized linear models method, Different superscripts in the columns above indicate significant differences (P<0.01), ± standard deviation.
Factor A : A1: tapioca flour; A2: patin flour; A3: cassava flour; A4: karagenan flour; A5: palm sugar; and Factor B : B1: 100°C; B2: 110°C; C3: 120°C.

Table 7 - Mean value of water absorption of sugarcane tops and tithonia based wafers (%)

Factor A	Factor B	Factor C		
		C1	C2	C3
A1	B1	$114.43^{cdefg} \pm 2.67$	$111.25^{abcde} \pm 1.55$	$115.85^{cdefg} \pm 4.38$
	B2	$114.09^{cdefg} \pm 1.65$	$119.17^{fg} \pm 4.38$	$116.30^{defg} \pm 1.35$
	B3	$115.56^{cdefg} \pm 1.28$	$113.01^{abcdefg} \pm 2.20$	$104.22^{a} \pm 0.97$
A2	B1	$119.58^{g} \pm 2.02$	$117.95^{efg} \pm 0.75$	$114.35^{cdefg} \pm 4.67$
	B2	$118.89^{fg} \pm 1.90$	$115.98^{cdefg} \pm 1.12$	$116.55^{defg} \pm 3.92$
	B3	$117.39^{defg} \pm 3.04$	$115.62^{cdefg} \pm 2.88$	$115.33^{cdefg} \pm 4.51$
A3	B1	$117.74^{efg} \pm 1.57$	$117.33^{defg} \pm 1.25$	$114.82^{cdefg} \pm 3.70$
	B2	$115.97^{cdefg} \pm 0.22$	$113.86^{cdefg} \pm 3.04$	$118.18^{efg} \pm 1.33$
	B3	$116.63^{defg} \pm 0.86$	$115.79^{cdefg} \pm 2.81$	$116.509^{defg} \pm 1.08$
A4	B1	$118.32^{efg} \pm 0.81$	$114.97^{cdefg} \pm 0.98$	$110.61^{abcd} \pm 1.19$
	B2	$116.63^{defg} \pm 2.30$	$112.78^{abcdefg} \pm 1.49$	$109.16^{abc} \pm 0.90$
	B3	$116.66^{defg} \pm 0.65$	$112.87^{abcdefg} \pm 1.54$	$105.94^{ab} \pm 1.90$
A5	B1	$118.14^{efg} \pm 2.48$	$116.76^{defg} \pm 1.61$	$115.20^{bcdefg} \pm 3.07$
	B2	$113.19^{bcdefg} \pm 5.47$	$112.73^{abcdefg} \pm 0.99$	$117.88^{efg} \pm 2.73$
	B3	$114.40^{cdefg} \pm 2.15$	$116.78^{defg} \pm 1.01$	$112.39^{abcdef} \pm 0.75$

Note: statistical further test using generalized linear models method, Different superscripts in the columns above indicate significant differences (P<0.01), ± standard deviation.
Factor A : A1: tapioca flour; A2: patin flour; A3: cassava flour; A4: karagenan flour; A5: palm sugar; and Factor B : B1: 100°C; B2: 110°C; C3: 120°C.

DISCUSSION

Wafer colour

Based on the interaction of factor A (application of different types of adhesive), factor B (drying temperature in the oven), and Factor C (length of time in the oven), the best wafer colour is found in the $A_1B_3C_3$ treatment, namely sugarcane tops and tithonia-based wafers (40: 60) using tapioca starch adhesive type which is baked at 120°C with a time of 20 minutes with an average of 3.73. The combination of sugarcane tops and tithonia gives a dark brown colour given the type of tapioca starch adhesive. Dark brown colour changes also occur due to a fairly high heating process of 120°C and are supported by the material of sugarcane tops and tithonia relatively the same. Lee et al. (2017) stated that the colour change that occurs during the heating process makes the material a darker brown colour. Type of adhesive Tapioca flour gives the best wafer colour, this is thought to occur because tapioca flour has the ability to bind the source of feed ingredients (sugarcane tops and Tithonia) in dry form is also getting better. Harahap et al. (2021) reported that tapioca flour is best used as a feed adhesive.

Wafer aroma

The aroma of wafers is an indicator that can be used to determine the presence or absence of damage through changes in aroma that occur in wafers, so as to determine the quality of wafers. The interaction that occurs between factor A, factor B, and factor C obtained the highest value in the $A_1B_3C_3$ treatment, namely sugarcane tops and tithonia-based wafers using tapioca starch adhesive material in the oven for 120°C for 20 minutes with a value of 3.70. The aroma of wafers is considered very well in terms of wafer quality which ranges from 3 - 3.9. Sugarcane shoots and tithonia have a distinctive aroma so that the aroma produced is quite good in wafer quality. In this study, the aroma produced is good enough so that it is not rancid. Reed (2005). That changes in the rancid aroma of wafers are caused by the fermentation of wafers which makes the aroma rancid.

Wafer texture

Wafer texture is an indicator to see how strong, dense, and rough or slimy so that the quality of a wafer is obtained. The interaction that occurs between factor A, factor B, and factor C obtained the highest value in the $A_1B_3C_3$ treatment, namely sugarcane tops and tithonia-based wafers using tapioca starch adhesive material in the oven for 120°C for 20 minutes with a value of 3.63. The texture in the $A_1B_3C_3$ treatment was considered very good with the description (Has a firm, dense texture (not easily broken). Animal feed wafers that have a firm and dense texture are good and not easily broken when given to livestock. The best wafer texture is found in the $A_1B_3C_3$ treatment, this occurs because the use of tapioca which is baked at 120°C for 20 minutes provides a better texture than other treatments. Tapioca is one of the best types of adhesives in making wafers. Tapioca flour produces the best physical properties of wafers (Fayzullahogglu, 2017; Sandi et al., 2015; Sudekum et al., 2008). A good texture is also supported by the oven temperature of 120°C and an oven time of 20 minutes, where the higher the temperature and the longer the oven time, the better the texture of the wafers will be.

Wafer density

The interaction that occurred between factor A, factor B, and factor C obtained the highest value of wafer density in the $A_1B_3C_3$ treatment, namely sugarcane tops and tithonia-based wafers using tapioca starch adhesive material in the oven for 120°C for 20 minutes with a value of 5.68. This happens because in the $A_1B_3C_3$ treatment using tapioca flour in the manufacture of wafers, tapioca contains starch which is very good as a designer material in the manufacture of wafers, so as to get a very good density value, this also happens because the temperature and time used is 120°C for 20 minutes longer than other treatments so that starch is more optimal in unification with sugarcane tops and tithonia. Tapioca starch contains 17% amylose and 83% amylopectin which is hygroscopic (Da Silva et al., 2022). The ratio of amylose and amylopectin affects the starch gelatinisation process and digestibility (Retnani et al., 2023). Amylopectin is sticky while amylose is hard (Deng et al., 2010 and Hadipernata et al., 2023). The gelatinisation process during heating will cause the formation of hydrogen bonds that will bind the feed components resulting in a compact texture and not easily destroyed, low water absorption thus increasing feed efficiency (Retnani et al., 2023) and causing changes in the physical characteristics of feed (Zhu et al, 2016 and Milawarni et al., 2020).

Water absorbency of wafers

Water absorption is a variable that shows the ability of wafer feed to attract surrounding water (air humidity) which binds to material particles or is retained in the pores between material particles. The interaction that occurred between factor A, factor B, and factor C obtained the lowest value of wafer water absorption in the $A_1B_3C_3$ treatment, namely sugarcane tops and tithonia-based wafers using tapioca starch adhesive material in the oven for 120°C for 20 minutes with a value of 104.22. This happens because in the $A_1B_3C_3$ treatment using tapioca flour in the manufacture of wafers, tapioca contains quite high starch, starch will undergo a galatinisation process during the heating process. So that it can reduce the water absorption of the wafer. Harahap et al. (2021) reported that tapioca flour is best used as a feed adhesive. This is related to the starch content in the adhesive material which will undergo a gelatinisation process during heating. The higher the starch content, the higher the gelatinisation process will be because the granule structure is tighter which will glue the feed, so the lower the water absorption. Water absorption is related to particle density. The higher the water absorption, the lower the particle density, and vice versa. The water absorption capacity of the cloud is inversely proportional to the density and texture will cause the water absorption capacity to decrease (Silaban et al., 2020). High particle density indicates better wafer quality because wafers are denser, harder, more durable and easier to handle, store or transport (Adelina et al., 2021) but has disadvantages because livestock have difficulty consuming them (Muralidharan et al., 2016) and reduce palatability (Retnani et al., 2023 and Sukaryana et al., 2020).

CONCLUSION

From the research it can be concluded that there are interactions on the physical properties of wafers (colour, aroma, and smell), density and water binding capacity. The best adhesive in making sugarcane tops (*Saccharum officinarum*) and Tithonia (*Tithonia diversifolia*) based wafers is tapioca flour with a temperature of 120°C for 20 minutes, with physical properties such as colour, aroma, and excellent texture with a range (3.73, 3.70, and 3.63), density with a value of 5.68 g/cm3, and water binding capacity with a value of 104.22%.

DECLARATION

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Author participation

N. Jamarun and M. Zain contributed to research concepts, technical and logistic support, and supervised the research. R. Pazla and G. Yanti contributed to experimental design, data collection and execution. Z. Ikhlas contributed to data collection, analyses and the write up of the manuscript. B.V Utami contributed to writing the final drafted manuscript. All authors have read and approved the final manuscript

Data availability

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

Competing interests

We declare that there are no conflicts of interest with any financial organisation regarding the material discussed in this paper.

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