THE PROCESSING TECHNIQUE AFFECTS THE PHYSICOCHEMICAL AND TEXTURAL CHARACTERISTICS OF PURPLE YAM BASED GLUTEN-FREE DOUGH

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ABSTRACT

Purple yam tuber in the form of flour has been applied for functional food products. Processing purple yam tubers into flour eliminates many beneficial compounds of the tubers. Another alternative for processing purple yam tubers is to process them directly into a paste to be mixed into the dough. This study was carried out to determine the effect of the processing technique of yam tuber on the texture profile of gluten-free dough made up of yam tuber and modified cassava flour (mocaf). Four (4) types of processing techniques were applied to produce purple yam+mocaf dough. First (ST), steaming yam tuber, mashing + mocaf + water. Second (SST), steaming slice of yam tuber, mashing + mocaf + water. Third (SCT0.5), soaking slices of yam tuber in citric acid 0.5%, mashing + mocaf + yam tuber mucus. The last (SCT1) is soaking slices of yam tuber in citric acid 1%, mashing + mocaf + yam tuber mucus. The result showed that the amount of water, the ratio between purple yam paste and mocaf, the lead time, and the processing technique play important roles in shaping the texture of the dough. The third technique (SCT0.5) produced higher hardness, adhesiveness, springiness, and cohesiveness dough than the other techniques. However, none of the texture profiles strongly correlate with the dietary fiber content. These results can be used better to understand the free gluten food application of yam tuber.

Keywords: Functional; Gluten Free; Mocaf; Yam

INTRODUCTION

Purple yam tuber (*Dioscorea alata*) is a potential source of carbohydrates that can be developed as a functional food ingredient. The tuber contains high levels of dietary fiber, which correlates with lowering blood lipids and sugars (Hernandez, 2015; Trask et al., 2013). Currently, the utilization of purple yam tubers for food product is still in the form of flour and used for a partial substitution of wheat. For example, the current maximum substitution of wheat using purple yam flour in bread only reaches 30% (Amandikwa et al., 2015; Nindjin et al., 2011). Gluten in wheat is the key factor affecting the quality of baked products. It is a complex protein mixture of gliadin and glutenin, mainly in wheat. Gluten performs many roles in most baked goods because of its distinct viscoelastic qualities. Gluten helps set the crumb structure, gives the dough cohesion during processing, aids in batter emulsification and viscoelasticity, and gives bread texture elasticity. Therefore, creating a gluten substitute and high-quality baked goods without gluten is a significant technological difficulty. Many substances have been added to the recipes of gluten-free products to address the issue of the absence of viscoelasticity. One of them is hydrocolloids such as inulin (Kiumarsi et al., 2019), xanthan gum (Milde et al., 2020; Wu et al.,

2022) or guar gum (Mæhre et al., 2021; Sheikholeslami et al., 2018). Hydrocolloid absorbs water through its hydroxyl groups, creating a viscoelastic network to balance the lack of gluten. Furthermore, hydrocolloid increases viscosity and incorporation of air into the dough, leading to a better specific volume of gluten-free dough when baked (Culetu et al., 2021). Purple yam naturally contains hydrocolloids recognized as glucomannan (Fortuna et al., 2020; Ma et al., 2020). Due to its solubility in water, the substance is reduced during tuber processing into flour, which involves soaking, blanching, and drying. This natural hydrocolloid in purple yam may be preserved by applying purple yam tuber as mashed boiled tuber.

Mocaf (modified cassava flour) is one of the food ingredients that can be used in gluten-free formulations. Mocaf is fermented cassava flour made using the modified cassava cell principle. Cellulose enzymes produced by growing microorganisms can harm cassava cell walls. These microbes hydrolyze starch to create sugars, generating the enzymes needed to change the sugars into organic acids, mainly lactic acid (Apriliani and Mulyadi, 2022). The changes alter the viscosity, gelation potential, and rehydration potential of cassava flour, leading to its enhanced ability to complement purple yam gluten-free dough.

Several techniques in the production of purple yam paste for gluten-free dough and its complement, such as mocaf, may affect the characteristics of the dough. Unfortunately, inadequate information on these areas restricts the further application of yam tuber and mocaf for gluten-free products. This study aimed to investigate the physicochemical and textural characteristics of the gluten-free dough composed of purple yam paste, which is processed using several techniques, and mocaf.

METHODS

This study used purple yam (*Dioscorea alata*) harvested at Jangkat, Jambi Province, and commercial mocaf from a local supermarket. The chemicals were from Sigma Aldrich, Germany.

Gluten-Free Dough Preparation

Purple yam tubers were cleaned and peeled. The next step was different depending on the processing techniques as the treatment.

a. Treatment 1 (ST)

This treatment was steamed yam tuber + water. The cleaned and peeled tuber was steamed at 100°C for 15 minutes, cooled at room temperature, and then crushed into a paste. 50 g of this paste was mixed with 50 g of mocaf and 50 g of water to obtain an ST dough.

b. Treatment 2 (SST)

This treatment was slice of steamed yam tuber + water. The cleaned and peeled tuber was cut into slices measuring ± 0.5 cm, steam-cooked for 15 minutes at 100°C, cooled at room temperature, and then crushed into a paste. 50 g of this paste was mixed with 50 g of mocaf and 50 g of water to obtain an SST dough.

c. Treatment 3 (SCT0.5)

This treatment was slice of yam tuber, citric acid soak 0.5% + yam tuber mucus. The cleaned and peeled tuber was cut into slices measuring ± 0.5 cm, soaked for 30 minutes in a 0.5% citric acid solution, steam-cooked for 15 minutes at 100°C, cooled at room temperature, and then crushed into a paste. 50 g of this paste was mixed with 50 g of mocaf and 50 g of mucus to obtain an SCT0.5 dough.

d. Treatment 4 (SCT1)

This treatment was slice of yam tuber, citric acid soak 1% + yam tuber mucus. The cleaned and peeled tuber was cut into slices measuring ± 0.5 cm, soaked for 30 minutes in a 1% citric acid solution, steam-cooked for 15 minutes at 100°C, cooled at room temperature, and then crushed into a paste. 50 g of this paste was mixed with 50 g of mocaf and 50 g of mucus to obtain an SCT1 dough.

The dough was obtained by kneading the mixture using a medium-speed mixer until compact dough was created. The dough will be subjected to several analyses, including a texture analyzer to determine cohesiveness, adhesiveness, springiness, and hardness (Gu et al. 2023; Khemiri et al. 2020), proximate analysis of its chemical composition, determination of its starch, crude fiber, soluble, insoluble, and total dietary fiber contents (Ijarotimi et al., 2022).

Texture Profile Analysis (Khemiri et al., 2020)

The characteristics of the dough were studied using texture profile analysis, where measurements were carried out using a texture analyzer called TAXT2i (Stable MicroSystems). The measurements using a texture analyzer show a curve that provides information about changes in force over a specific time interval. During measurement, a load of a certain magnitude is given to a sample of a particular size, a certain distance, and an exact speed two (2) times. In this research, a dough sample weighing 25 g was formed into a round shape with a diameter of 2.5 cm, given an SMS p/27 probe load with a speed of 5 mm/s, a distance of 30%, and a trigger of 5 g.

The TPA test followed the following settings:

1. First compression. The probe descends towards the sample. When the probe touches the sample, the measurement begins and the probe descends, pressing the sample at a speed of 5 mm/s with a distance of 30% of the total sample (1.6 seconds)
2. First release. When the probe reaches the desired distance, the probe then rises back away from the sample at a speed of >5 mm/s, returning to its original position
3. Pause. During the pause process, the sample returns to its original position, depending on its characteristics, before being given a second compression.

The hardness value (gF) is calculated from the peak force value during the first compression. Adhesiveness (gF.s) is obtained from the area under the first negative peak curve. Cohesiveness has no units because it is the ratio between the total area under the second compression curve and the total area under the first compression curve. Springiness (%) is a percentage that shows how much the sample returns to its original height. For every sample, measurements were made at 20±1°C at least twice.

Crude Fiber (AOAC, 2009)

1g (x) of dough sample was transferred to a 250 mL beaker. After that, 50 mL of 0.3 N H_2SO_4 solutions was added. The beaker with the sample was heated on a hot plate for 30 minutes, added 1.5 N NaOH solution, and heated for 30 minutes. The following step involves filtering using filter paper of known weight (A). 25 mL of acetone, 50 mL of 0.3 N H_2SO_4, and 50 mL of hot water were used to wash the residue. Filter paper and the residue are placed into porcelain and dried in an oven at 105°C to 110°C, after which it is placed in a desiccator for 15 minutes and weighed until it reaches a constant weight (Y). The dry matter was burned in a furnace for 6 hours at 600°C. The ash was weighed after being chilled for 24 hours in a desiccator (Z). Equation (1) was used to determine the crude fiber content.

$$\text{Crude fiber content } (\%) = \frac{Y-A-Z}{x} \times 100\% \quad \text{.........(1)}$$

Dietary Fiber (Ijarotimi et al., 2022)

Dough samples (two duplicates for each measurement) were dried and gelatinized with Termamyl (heat-stable α-amylase) and then enzymatically digested with protease and Amyloglucosidase to remove protein and starch. The solution was filtered, and the residue was washed using distilled water. SDF was determined in both the filtered solution and the wash water, while IDF was determined in the residue. Determination of SDF was carried out by precipitating the solution using ethanol. For IDF determination, the residue was dried, weighed (W_1), and washed using acetone and 95% ethanol. One duplicate further underwent protein determination (W_2), while the other duplicate was burned at 525°C to measure the amount of ash (W_3). IDF was calculated by subtracting W_2 and W_3 from W_1.

Statistical Analysis

The textural properties and chemical composition of the gluten-free dough, as affected by several techniques, were presented as average from 2 replications ±

standard deviation. The correlation between chemical composition and textural properties of the dough was analyzed using Pearson correlation. The correlation coefficient higher than 0.7 was considered to have a strong correlation, and the correlation of $p < 0.05$ was considered statistically significant.

RESULT AND DISCUSSION

Physical Properties of the Free-Gluten Dough

The amount of water used in making the dough determines the characteristics of the dough. Yam tuber is a slimy tuber due to its mucus content. During steaming, some mucus dissolves in the water vapor. Mucus in tubers is a non-starch protein-polysaccharide complex (Fortuna et al., 2020), which can be damaged by heat and the presence of water. Heat denatures proteins so that they lose their ability to bind to polysaccharides. Proteins and polysaccharides, including glucomannan (Fortuna et al., 2020), are water soluble and easily lost during steaming. Steamed Yam tuber as a single ingredient can produce a compact dough. The slime that remains on the steamed yam helps mix and unite the components in the tuber. The hardness characteristics of the yam tuber dough can be seen in Table 1.

Table 1. The effect of the freshness of the dough on the hardness of the purple yam paste + mocaf dough

Amount of Water (%)	Hardness (gF)	
	Fresh	Not Fresh
40	1059.76	652.16
45	1132.11	590.00
50	599.17	548.22
60	325.06	293.47
70	212.97	162.02

The delay from manufacturing to testing processes also affects the hardness value (Monthe et al., 2019). The hardness value of the dough based on its freshness level is shown in Table 1. At the optimal addition of water (50% for 100 g of steamed yam tuber and mocaf mixture), the fresh dough has a slightly higher hardness than the dough left for 14 hours (not fresh). The increase in dough hardness is due to the retrogradation process, a process of rearranging the structure of starch molecules after gelatinization. Starch gelatinization occurs when cassava tubers are steamed when the starch molecules absorb water to a certain point where the starch granules swell and burst. Dough hardness occurs more quickly at the beginning of the retrogradation process and slows down afterward (Liu et al., 2023).

The formulations of steamed yam tuber and mocaf significantly affect the compactness of the dough and the ease with which the dough is processed into sheets. All formulations produce dough that can be made into sheets, but with a lower difficulty level if the number of mocaf used is higher. The 1:1 formulation was chosen because it is the easiest to form an intact sheet and produces the most compact dough. As seen in Table 2, more mocaf and water produced dough with a lower hardness.

Texture Profile of Free-Gluten Dough

The tuber processing method also influences the hardness of the purple yam+mocaf dough. As shown in Table 3, slicing the purple yam tuber before steaming increase the hardness of the purple yam+mocaf dough. Purple yam mucilage is a source of hydrocolloids (Fortuna et al., 2020) where hydrocolloids are known to improve the dough characteristics of bread and noodles (Calle et al., 2020; Monthe et al., 2019; Raungrusmee et al., 2020; Zhang et al., 2023; Zhao et al., 2021). Removing the mucilage from the yam tubers while soaking in citric acid solution and adding it back to form the dough reduces the hardness of the dough.

Adding liquid in the form of purple yam mucus to the dough helps to form a more compact and flexible dough than adding liquid in the form of water alone. However, using acid to extract the mucus has a reduced effect (Table 3). Protein networks containing acids can help increase the viscoelasticity of purple yam and mocaf particles, resulting in a more compact and flexible dough (Zhang et al., 2023).

Table 2. Purple yam paste + mocaf dough hardness in various formulations

Purple Yam Paste (g)	Mocaf (g)	Water (g)	Hardness
50	0	0	217.20±16.32
50	10	10	249.83±171.32
50	20	20	148.88±16.32
50	30	30	149.90±17.34
50	40	40	125.43±1.02
50	50	50	127.46±11.22
50	60	60	127.46±47.93

Table 3. Effect of purple yam processing method on the hardness of purple yam paste + mocaf dough

Method	Hardness (gF)	Adhesiveness (-gs)	Springiness (%)	Cohesiveness
ST	191.30±79.62	36.59±8.42	40.04±13.31	0.40±0.00
SST	191.15±72.34	35.53±11.56	38.83±16.24	0.39±0.03
SCT0.5%	259.25±24.11	51.28±3.68	51.28±3.68	0.45±0.02
SCT1%	241.90±30.26	26.63±6.68	26.63±6.68	0.40±0.04

The compactness of the dough, expressed in the cohesiveness value, is proportional to the stickiness of the dough, which is expressed in the adhesiveness value, and the flexibility of the dough, described in the springiness. Judging from its cohesiveness and springiness, the use of purple yam mucilage is beneficial, but from the point of view of its adhesiveness, this is undesirable. Adhesiveness indicates the adhesive properties of the dough on the processing tool, for example, the kneading blade, the inside of the mixing bowl, or the dough transfer tool, so that the higher the adhesiveness of dough, the greater the loss of dough during the processing (Wang et al., 2022). Adhesiveness is influenced by interactions between OH groups in the dough which can come from gelatinized starch (Gu et al., 2023), protein (Liu and Zhang, 2022; Wang et al., 2022), hydrocolloids, and water (Liu et al., 2022). In this study, adhesiveness was higher in dough with higher levels of dietary fiber and water content (Table 4). Considering the role of hydrocolloids in forming dough cohesiveness, dough characteristics can be improved using thicker purple yam mucus obtained by reducing the amount of water during extraction.

The presence of acid produces a protein network that helps increase cohesiveness and springiness. To ensure this, the same test was carried out on the second treatment of purple yam+mocaf dough (sliced and steamed tubers) with adding one food ingredient, which is a source of protein, namely powdered milk. This powdered milk contains 18.5% protein and 22.2% fat. Powdered milk, especially skimmed milk powder, improves dough structure by forming a stable network (Cappelli et al., 2020). Fat can generally form a plastic dough with better cohesiveness (Sudha et al., 2014). The results of the texture profile analysis test for purple yam+mocaf+milk powder dough can be seen in Table 5.

Several types of protein are reported to increase dough hardness, for example, zein protein from corn (Zhang et al., 2023) and protein from apricot kernels (Liu and Zhang, 2022). It is also possible that the similar effect shown by this research is due to protein in the milk powder. While protein can increase hardness, fat has the opposite effect. Fat is known to interfere with the formation of the gluten network; the magnitude of the impact depends on the type of fat used (Kouhsari et al., 2022), so its presence can reduce dough hardness (Liu and Zhang, 2022). Apart from protein and fat, powdered milk also contains water in the range of 4%. The more milk powder is added, the more water increases so that the dough's hardness decreases (Cappelli et al., 2020; Liu et al., 2023). According to Liu et al. (2022), sugar strongly correlates with dough cohesiveness. In this study, the milk powder used contained 40% sugar, so it can be understood that increasing the amount of powdered milk in the dough increases the cohesiveness of the purple yam+mocaf+milk gluten-free dough. Besides sugar, milk protein may also increase the cohesiveness value of the dough, the same as zein protein in rice flour dough (Zhang et al., 2023). The high-fat level in milk has a plastic effect on the dough, which may also increase its cohesiveness value (Sudha et al., 2014).

Milk powder in the purple yam+mocaf+milk powder dough increases the springiness of the dough (Table 4). The springiness of a dough shows its ability to recover after experiencing deformation. The springy dough is indicated by its characteristic of quickly returning to its original position when pressed. This characteristic can be easily demonstrated in dough made from wheat, where the protein can produce a solid but flexible gluten network. In gluten-free dough, this characteristic is usually formed by proteins or hydrocolloids that are deliberately added to the dough (Cappelli et al., 2020; Liu et al., 2022; Zhang et al., 2023). In this research, milk protein is probably one factor that increases the springiness value of purple yam+mocaf+milk powder dough compared to purple yam+mocaf dough alone. However, it should also be noted that the upward pull of the dough may also influence high adhesiveness in purple yam+mocaf+milk powder dough during the first unloading pressure.

Table 4. Effect of purple yam processing method on the chemical composition of purple yam paste + mocaf dough

Component*	ST	SST	SCT0.5%	SCT1%
Water (%)	64.56±0.08	64.27±0.01	66.19±0.14	67.63±0.21
Ash (%)	1.74±0.03	1.70±0.07	1.77±0.07	1.61±0.15
Fat (%)	0.19±0.02	0.13±0.03	0.31±0.03	0.14±0.01
Protein (%)	4.62±0.47	3.73±0.04	3.82±0.10	4.60±0.17
Crude Fibre (%)	0.68±0.00	0.71±0.02	0.45±0.01	0.52±0.01
Insoluble Dietary Fibre (%)	5.22±0.01	5.44±0.08	5.14±0.09	6.42±0.11
Soluble Dietary Fibre (%)	0.12±0.01	0.13±0.00	0.13±0.01	0.15±0.01
Starch (%)	80.40±0.72	80.36±0.40	77.38±0.58	79.00±0.50
Sugar (%)	0.99±0.01	1.99±0.01	0.40±0.01	0.64±0.01

* Dry weight percentage, except for water, which is in wet bases

Table 5. Effect of milk powder on the hardness of purple yam+mocaf+milk powder dough

Milk Powder (% w/w)	Hardness (gF)	Adhesiveness (-gFs)	Springiness (%)	Cohesiveness
0	156.70±14.42	25.72±8.73	44.01±7.58	0.36±0.04
5	145.40±2.97	33.73±14.33	51.43±11.37	0.41±0.08
10	149.15±30.62	50.32±16.86	69.67±25.31	0.51±0.11
15	107.15±13.79	54.82±9.74	100±0.00	0.73±0.02
20	86.45±19.45	55.15±11.70	100±0.00	0.80±0.05

*% w/w (weight of milk powder/ weight of purple yam+mocaf*100)

Table 6. Correlation coefficients between the chemical composition and texture profile of purple yam+mocaf dough

Chemical composition	Hardness	Adhesiveness	Springiness	Cohesiveness
Water	0.50	-0.18	-0.30	0.20
Ash	0.00	0.76*	0.72 ns	0.48
Fat	0.38	0.77*	0.62	0.72ns
Protein	-0.05	-0.51	-0.46	-0.28
Crude fiber	-0.60	-0.34	-0.16	-0.57
Insoluble dietary fiber	0.15	-0.68	-0.67	-0.33
Soluble dietary fiber	0.20	-0.62	-0.63	-0.28
Total dietary fiber	0.15	-0.67	-0.67	-0.33
Starch	-0.58	-0.51	-0.33	-0.65
Sugar	-0.49	-0.25	-0.11	-0.50

*The correlation coefficient is significant at 0.05; ns = not significant

Correlation Analysis

As shown in Table 6, there are a few correlations between the texture profile and the chemical composition. Only adhesiveness shows a relatively strong and significant correlation ($p<0.05$), with the correlation coefficients being 0.77 and 0.76 for fat and ash content, respectively. A fairly strong correlation exists but not significant between cohesiveness and fat content (correlation coefficient = 0.72). According to Liu et al. (2022), cohesiveness is highly correlated with dietary fiber content, but in this study, there was a weak and not significant correlation between them. However, the dietary fiber content showed a relatively strong correlation but not significant with adhesiveness and springiness. The type of dietary fiber, whether soluble or insoluble, may influence the outcome of correlation studies. The apricot dietary fiber in the previous research contains a comparable amount of soluble and insoluble dietary fiber. In contrast, in this study, the dietary fiber is composed mainly of insoluble dietary fiber.

CONCLUSION

The processing technique affects the texture profile of the purple yam+mocaf dough. The result showed that the processing technique that preserved more dietary fiber did not produce the most compact dough (highest cohesiveness). However, the dough made by slicing yam tuber, soaking it in citric acid 0.5% and mashing, mixed with mocaf and tuber mucus, showed up to have higher cohesiveness despite its less dietary fiber content than the similar technique, which used 1% citric acid. The fairly strong correlation between fat/cohesiveness and fat/adhesiveness suggests that the texture profile of a purple yam+mocaf dough may be controlled by setting a careful formulation with fat.

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