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The Effect of Purple Sweet Potato Flour (*Ipomoea batatas L*) as Wheat Flour Substitution on Physicochemical and Sensory Properties of Crackers

M. Kurniati[1], Muhaimin[2], Ulyarti [1,3]
[1] Department of Agricultural Technology, Faculty of Agriculture, University of Jambi
[2] Faculty of Pharmacy, University of Padjadjaran
[3] Centre of Excellence Bio-Geo Material and Energy, University of Jambi

Email: ulyarti@unja.ac.id

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Abstract:
The changes in main ingredients may affect the characteristics of cracker. This study aimed to determine the effect of purple sweet potato flour as a substitute for wheat flour on the physicochemical and sensory properties of crackers. This study used a Completely Randomized Design (CRD) consisting of 6 levels of purple sweet potato flour concentration as treatment (0%, 10%, 20%, 30%, 40%, and 50%) and 3 replications. The concentration of purple sweet potato flour has shown a significant effect on volume development, brightness value (L*), anthocyanin content, and sensory properties (color, taste and overall acceptance), but has not shown significant effect on the texture and sensory property (texture) of crackers. The substitution of 50% wheat using purple sweet potato flour produced the best crackers with hardness 1098.80 gF, development volume -19,33%, L* 72, a* 30, b* 4.33 and the anthocyanin contents of 162.02 mg of Cyanidin 3-glucoside/100g. The cracker contains 6.25% moisture content, 3.00% ash, 7.47% protein, 19.00% fat, 1.00% crude fiber and 64.28% carbohydrate.

Keywords: Crackers, Physicochemical, Sensory, Purple Sweet Potato, Flour

1. Introduction

Indonesia has various local food sources that have not been utilized optimally, one of which is sweet potatoes (*Ipomoea batatas L.*). Sweet potato is an agricultural product that does not last long and rots easily. Its process into flour increases its value added and uses for food production. As there is an increase in public awareness for the importance of healthy food, people tend to consume food with health benefit. Sweet potatoes are the fourth highest source of carbohydrates after rice, corn and cassava. Apart from being a source of energy, sweet potatoes contain β-carotene, vitamin C, niacin, riboflavin, thiamin and minerals. According to Xiaolin et al (2024), based on color, sweet potatoes are divided into white sweet potatoes, orange sweet potatoes and purple sweet potatoes. Purple sweet potatoes have nutritional content that is not much different from other types of sweet potatoes. However, purple sweet potatoes have other advantages, namely the high content of anthocyanin, which is an antioxidant compound.

The high anthocyanin content in purple sweet potatoes is the potential for functional food ingredient. Anthocyanin is a flavonoid compound which has the ability to act as an antioxidant and a pigment which causes the tuber flesh to turn purple. Functional food is food that provides health benefits, apart from its function as a basic nutrient (Silalahi, 2006). The increase in the population welfare has encouraged changes in eating patterns which lead to the increase in various types of degenerative diseases. Awareness of the large relationship between food and the possibility of disease has changed people's view that food is consumed not only for satiety but also for health (Marsono, 2007).

Anthocyanins in purple sweet potatoes also have physiological functions, for example antioxidant, anticancer, antibacterial, protection against liver damage, heart disease and stroke. The dietary fiber content and relatively low glycemic index (GI) value of sweet potatoes provide added value to this commodity as a functional food. Flour is an alternative product for a more wide application of purple sweet potato. The nutritional content of purple sweet potato flour includes water content of 7.28%, protein 2.79%, fat 0.81%, fiber 4.72% and carbohydrates 83.81% (Ginting et al, 2011). This composition of flour is suitable for crackers processing. Crackers are a type of biscuit made from hard dough, through a fermentation process, have a flat shape, taste salty, and crunchy. Crackers are very popular and can be consumed by everyone from children to the elderly. Generally, crackers on the market use wheat flour as raw material, which is currently still imported. Currently, several similar studies in Indonesia have used local materials as substitutes for crackers preparation. Crackers have been made by substituting flour with catfish flour and carrot flour (Arza, et al, 2017), a substitution of 25 grams each has an effect on the quality of the crackers, namely 16.19% protein content as well as the sensory parameters of color, texture, aroma and taste. Substituting wheat with gadung flour (Anderson, 2018) with a 30% substitution has an effect on the expansion volume, water content, hardness and crispiness. Based on these, this research was carried out to determine the effect of wheat substitution using purple sweet potato flour on the physicochemical and sensory properties of crackers.

2. Research Methods

Material

The materials used were purple sweet potato, wheat flour, margarine, butter, skim milk, baking powder, powdered sugar, yeast, water and salt. The tools used in making these crackers were baking oven, analytical scales and color reader.

Methods

This research was conducted using Completely Randomized Design (CRD) with treatment substitution of wheat flour using purple sweet potato flour (0%, 10%, 20%, 30%, 40%, 50%) and 3 repetitions.

Research Procedures

Flour Preparation

The preparation of purple sweet potato flour is done by sorting the purple sweet potatoes, cleaning them from the dirt, peeling and soaking the peeled tubers in water to prevent a browning reaction. The clean tubers are sliced into 1 cm thickness, steamed at 100^{o}C for 7 minutes, dried in an oven at 60^{o}C for 6 hours. The dried sweet potatoes are then processed into flour by grinding and sieving using a 60 mesh sieve until purple sweet potato flour is obtained.

Crackers Preparation

The ingredients are weighed based on the cracker formulation. Salt and water are placed in a bowl and stirred until salt is dissolved. The purple sweet potato flour, wheat flour, yeast, powdered sugar, butter and margarine are mixed in another bowl and stirred until evenly mixed (dry ingredients). Pour salty water into the dry ingredients and kneaded by hand until smooth. The dough is rested while being covered with a cloth dampened with warm water. This fermentation process is carried out for 30 minutes. After the fermentation process is complete, the dough is made into a sheet measuring 5 cm long, 3 cm wide and 2 mm thickness. The dough was rested for 5 minutes and baked in the oven at 160^{o}C for 20 minutes, followed by cooling for 5 minutes at 25^{o}C-30^{o}C.

Texture (Baer and Dilger, 2014)

Texture measurements are carried out using the Steven LFRA (Leatherhead Food Research Association) Texture Analyzer. The Steven LFRA Texture Analyzer tool is set first before measurements are taken. The settings for the Steven LFRA Texture Analyzer tool are as follows. Mode: measure force in compression (measure the amount of force needed to compress the sample), Plot: Final, Option: Normal, Trigger: Auto 4g standards, Distance: 3mm, Speed: 0.5 mm/s.

The crackers to be measured are placed on the supporting table plate. Press the start button on the Steven LFRA Texture Analyzer tool. Then the probe presses the crackers at a speed of 0.5 mm/s until the pressing distance is 3 mm. The probe used is cylindrical in shape with a diameter of 2 mm. The trigger type used is the auto type. In this type, the probe will automatically search the sample surface. The texture value will be displayed on the tool display. The texture value is expressed in gram force (gF) units.

Crackers Development Volume (AACC, 2000) modified

Calculation for the volume of crackers was taken by measuring the length, width and height of the crackers (before being baked = V_1 and after being baked = V_2). The percentage volume of crackers expansion was calculated using formula:

$$\text{Development Volume} = \frac{(V2-V1)}{V1} \times 100\%$$

Color (Andarwulan, et al., 2011)

Change of color was obtained using equation below. The color parameter was measured using Adobe Photoshop with LAB colour system.

$$\Delta E_x = \sqrt{(L_x - L_0)^2 + (a_x - a_0)^2 + (b_x - b_0)^2}$$

Note:

ΔE_x = Change in color sample x when compared to control (0% substitution)
L_x = Lightness for sample x
L_0 = Lightness for control
a_x = Redness to greenness for sampel x
a_0 = Redness to greenness for control
b_x = Yellowness to blueness for sample x
b_0 = Yellowness to blueness for control

Anthocyanin Content (Santoscoy, et al., 2013)

Anthocyanin content were measured using the spectrophotometric method. A total of 1 gram of sample was extracted using 10 ml of methanol-acid solution which was made by mixing 95% methanol with 1 N HCl in a ratio of 85:15 (v/v). The sample was then supplied with nitrogen, shaken for 30 minutes and then centrifuged at 3000 g for 10 minutes. The absorbance of the supernatant obtained was read at wavelengths of 535 and 700 nm. Anthocyanin content is calculated using the following formula:

$$C = \{\frac{A535\ nm - A700\ nm}{\varepsilon}\} x100 * \text{(Volume of metanolic extract)} * \text{MW} * \frac{1}{sample\ weight}$$

Note:

C = Antosianin content (mg cyanidin 3-glucoside equivalents/gram sample)
Ɛ = molar absorptivity (for cyanidin 3-glucoside is 25.96/cm/M)
MW = Molecular weight cyanidin 3-glucoside is 449.2 g/mol

Sensory Properties

The texture of the crackers was tested by 25 semi-trained panelists using scale 1 to 5 which represents very not crispy to very crispy. The overall acceptance was also carried out by the same panelist using 1 to 5 scales from “dislike very much” to “likes very much”.

Chemical Composition

Ash, water, protein and fat content were measured using AOAC (2005) and carbohydrate content was calculated using by difference. These analyses were carried out for one sample which turns the best sample among the treatment.

3. Results and Discussion

Purple Sweet Potato Flour and Crackers

The yield of flour after being sieved using 60 mesh sieve was 23.06%. The purple sweet potato flour, as seen in Figure 1, contains high anthocyanin. The flour has a quite high lightness (L*), low protein content and considerable amount of crude fiber (Table 1). When this flour is used for wheat substitution, the crackers are obviously show an increasing purple color with increasing in percentage of substitution as seen in Figure 2. The higher amount of wheat substitution produces a more flat and dense cracker. The crackers contains 6.25% moisture content, 3.00% ash, 7.47% protein, 19.00% fat, 1.00% crude fiber and 64.28% carbohydrate.

Figure 1. Purple sweet potato flour

Table 1. The composition and color profile of purple sweet potato flour

Composition	Amount (%)
Water	7.00
Ash	2.00
Protein	4.39
Fat	3.00
Crude Fiber	4.00
Carbohydrate	83.61
Total Antosianin (mg Cyanidin 3-glucoside/100g)	208.878
L*	63.3
a*	+21
b*	-10.6

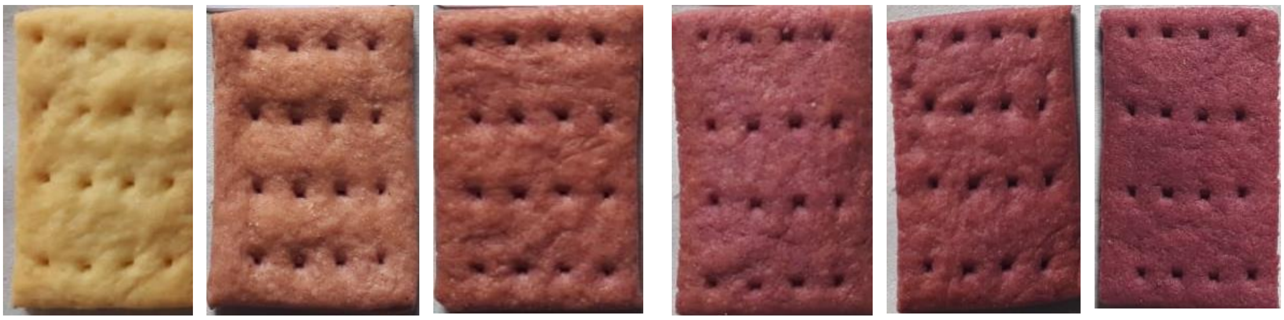

Figure 2. Crackers processed with different levels of wheat substitution using purple sweet potato flour

Physicochemical Properties of Crackers

The substitution of wheat flour using purple sweet potato flour affects development volume, lightness (L*) and anthocyanin content of the crackers, but it does not affect the hardness, a* and b* values of the crackers (Table 2).

Development occurs during the cracker dough fermentation process. Fermentation aims to ripen the dough until it is easy to handle and of good quality and forms the taste of crackers. The addition of *Saccharomyces cerevisiae* in form of yeast increases the expansion of the cracker dough, due to the presence of carbon dioxide gas (CO_2) produced by the yeast during fermentation. Sugar is used as a CO_2-producing substrate by yeast, which converts sugar into carbon dioxide gas and flavored compounds. The CO_2 gas that is formed is then trapped in the gluten network which causes the dough to expand (increase in volume). During fermentation acid and alcohol are also formed which contribute to the taste and aroma of the crackers, but the alcohol will evaporate in the process of baking the crackers.

Table 2. Average value of hardness, development volume, L*, a*, b*, and anthocyanin content of crackers processed with different level of wheat substitution using purple sweet potato flour

Wheat Substitution (%)	Hardness (gF)	Development Volume (%)	L*	a*	b*	ΔE	Anthocyanin (mg cyanidin 3-glucoside/100 g)
0	1,698.20	76.55c	82.67 c	3.33	33.33	-	0 a
10	1,500.73	37.99b	78.00 bc	16.67	30.00	14.51	66.48 b
20	1,295.73	21.33b	76.00 ab	19.67	19.00	22.73	115.89 c
30	1,399.67	-12.44a	73.67 ab	22.33	17.67	26.22	151.38 d
40	1,114.03	-16.11a	73.00 ab	26.33	8.67	35.08	154.82 de
50	1,098.80	-19.33a	72.00 a	30.00	4.33	40.82	162.01 e

Note: Numbers followed by the same letter in the same column are not significantly different (p>5%) according to DnMRT

The replacement of wheat by purple sweet potato flour reduces the amount of gluten in the cracker dough. The protein gliadin and glutenin when mixed with water produces gluten which is so elastics that able to retain the CO_2 and develop the dough and increase the volume. The reduction of gluten therefore is directly proportional to the decrease in the cracker's development volume produced by increasing the level of substitution (Table 2). This is similar to the results reported by Anderson (2018) using Gadung flour and Ulyarti et al. (2023a) using purple yam flour. For the purpose of functionality of product, the substitution can be carried out up to 30% according to Giannoutsos et al. (2023), but for this study the substitution can only be done maximum 20% to maintain acceptable development volume.

The L* value indicates the lightness level, where the value close to 100 means very lights while the value close to zero means very dark (Pardede & Ridwansyah, 2017). According to Rauf (2017), the L* value is influenced by the browning reaction that occurs during roasting, namely the caramelization reaction and the Maillard reaction. The caramelization reaction occurs due to heated sugar, while the Maillard reaction occurs between the reducing group of sugar and the amine group of protein. Purple sweet potato flour used in this study has higher carbohydrate content than wheat flour (67.77%) (Irmawati, 2014). The difference in the lightness level of the crackers produced is also caused by the difference in color of the flour used. The ΔE value of the crackers with the substitution using purple sweet potato flour is above 6 (Table 2) which indicates that there is a color difference that can clearly be seen by the human eye among the crackers.

Purple sweet potato flour contains anthocyanin pigments. The analysis of variance shows that the level of wheat substitution using purple sweet potato has a very significant effect on the anthocyanin content of crackers (Table 2). The anthocyanin pigment in purple sweet potato flour gives a purple appearance to the crackers. As seen in Table 2, the increase in the level of wheat substitution using purple sweet potato flour increases the anthocyanin content of the crackers. Similar to this is a report by Ulyarti et al (2023b) using purple yam flour for bread. The anthocyanin content in present study is lower than reported by Ulyarti et al. (2023b) with the anthocyanin content at 530 mg Cyanidin 3-glucoside/100 g of bread. The amount of anthocyanin content remaining from the process of baking crackers with 50% substitution shows that there is a decrease in the anthocyanin content when compared to same amount of the purple sweet potato flour used. The total anthocyanin in purple sweet potato flour was 208.878 mg Cyanidin 3-glucoside/100g crackers decreased to 162 mg/100 gram crackers. This occurs due to high temperature during baking process as anthocyanin is unstable at high temperatures (Ulyarti et al., 2019).

Conclusion

The wheat substitution up to 50% using purple sweet potato flour has a very significant effect on development volume, lightness value (L*), and total anthocyanin of crackers. Crackers with 50% wheat substitution were chosen as best substitution which produce crackers with hardness value of 1098.80 gF, development volume -19.33%, L* 72.00, a 30.00, b 4.33, anthocyanin content 162.02 mg Cyanidin 3-glucoside/100 g crackers.

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