Physicochemical characteristics and glycemic index of bread made from purple sweet potato flour, starch, fiber from solid waste of starch processing

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Abstract. This research was purposed to evaluate the characteristics of physicochemical, and glycemic index of bread made from purple sweet potato (PFSP) flour, starch, and fiber (solid waste of PFSP starch processing). The resulting breads were tested for the physicochemical characteristics and using non factorial completely randomized design as research design with 3 types of ingredient used in bread making as a treatment, namely composite flour from a mixture of PFSP flour, starch and fiber with a ratio 75: 5: 20; 100% PFSP flour, and 100% wheat flour. The results showed that differences in flour had a very significant effect on color, texture profile, ash, protein, fat, and total sugar content of bread. Bread made from composite flour in the form of a mixture of PFSP flour, starch and fiber flour, and also bread made from 100% PFSP flour has higher dietary fiber content than bread made from wheat flour. The daily energy sufficiency of the three types of bread is 10-12%. The glycemic index of bread made from composite flour, PFSP flour, and wheat flour were 41.3, 42.1, and 46.3, respectively, which were classified as low categories. Based on the results, PFSP flour, starch, and fiber flour can be used as wheat flour alternative in making bread.

1. Introduction
Sweet potato is one of the staple foods that has been the mainstay of food consumption in several country and the existence affects world food security [1]. The attractive colors, nutritional and the health benefits for degenerative disease prevention make purple sweet potato (PFSP) as the potential functional food [2]. In 2018, diabetics based on the results of blood glucose test in Indonesia were at 8.5% [3]. Type 2 diabetes is considering to metabolism complication that cause insufficient insulin secretion, impaired hepatic glucose production, that leads to β-cell dysfunctions [4]. Oxidative stress caused by free radicals is one of the factors that plays a role in β-cell dysfunctions that caused hyperglycemic. The high antioxidant diet helps in balancing antioxidants in the body that will prevent oxidative stress [5].
Anthocyanin possess antioxidant activity have a multiple health benefits such as anti-hyperglycemic, strong free radical activity scavenging, improve insulin secretion sensitivity, preventing insulin resistance, and inhibiting maltase activities that responsible for releasing glucose [6] and stable to thermal processing as steaming (121 °C) and baking (200 °C) [7]. The oligosaccharides found in purple sweet potato have been found to function as natural fiber that escalate product value [8].

Bread is generally a food product made from wheat flour dough with affixed yeast and roasted, it also allowed to add food additives and other edible ingredients [9]. Fiber add-on bread making believed can control postprandial blood glucose level [10]. It also inhibits rate of starch digestion and lowering blood glucose response because enzyme activities and digestion rate are inhibited. Digestive disease is also prevented by consuming non soluble dietary fiber [11].

Glycemic response refers to postprandial blood glucose at certain period [12]. The anthocyanin content in PFSP effective in controlling blood glucose of diabetic mice [13]. The goal of this study was to assess the characteristics of physicochemical and glycemic index of bread made from flour, starch and fiber of purple sweet potato processing towards glycemic response.

2. Materials and methods

Purple-fleshed sweet potato (PFSP) with similar harvest age and size (12-18 cm long and 200-300 grams in weight) were obtained from the West farmers in the Phak-Phak Regency North Sumatera Province. The ingredients for this study are sugar, bread improver, skimmed milk, yeast, eggs, shortening, salt, sesame, and xanthan gum. The chemical used in PFSP flour making were sodium metabisulfite.

2.1. Manufacturing of PFSP flour, starch and fiber flour from solid waste of PFSP starch processing

PFSP flour was prepared using the following procedure: fresh tubers were sorted, cleaned and washed from dirt, peeled, washed, sliced by using mechanical slicer to produced 2mm slice thickness. Sliced tuber were soaked in sodium metabisulfite solution in 2000 ppm concentration for 15 min, washed again with tap water and dried using drying oven at 55 °C for 12 h, milled using a disc mill, sieved using 80 mesh sieve machines, and obtained PFSP flour was packaged in airtight polyethylene plastic.

The extraction of PFSP starch was done by following procedure : the PFSP tubers were sorted, peeled, washed, and grated using mechanical grater. The grated tubers were added to the 2000 ppm of sodium metabisulfite solution with the ratio of mashed tubers: sodium metabisulfite solution was 1:3, pressed, and filtered using cheesecloth to separate filtrate and solid residue.

The filtrate was allowed to stand for 12 hours until a starch precipitate was obtained, which was then separated by removing the water. In order to obtained clean and white wet starch, it washed for three times, and then dried using drying oven at 50 °C for 12 h. The dried starch mashed using a kitchen blender and sieved to obtain PFSP starch with 80 mesh of particle size, which will be used as raw material for making bread. Solid residue from pressing mashed tubers, then dried with drying oven at 60 °C for 12 hours, mashed using a kitchen blender, and sieved through 60 mesh sieves, to obtain fiber flour from PFSP.

2.2. Bread formulation and manufacturing

The breads were prepared by using Hardoko et al. [14] procedure with modifications as on Table 1. Dried ingredients such as flour, sugar, yeast, skimmed milk, salt, and bread improver mixed using a mixer with low speed. Eggs and water were added gradually while mixing until the dough forms. After the dough formed, shortening was added as the mixer still on till the dough is dull. The resulting dough then proofed at room temperature for 30 minutes then pressed to release the gas. The dough was placed
in a mold, proofed for 1 hour, baked at 190°C for 30 minutes. The breads were cooled for 30 minutes at room temperature on a backing rack before sealing and packing in polyethylene plastic [14].

**Table 1. Bread making formulation.**

| Ingredients * | P1       | P2       | P3    |
|---------------|----------|----------|-------|
| PFSP Flour    | 300      | 400      | 0     |
| PFSP Starch   | 20       | 0        | 0     |
| PFSP Rich Fiber Flour | 80      | 0        | 0     |
| Wheat Flour   | 0        | 0        | 400   |
| Water         | 250      | 250      | 250   |
| Sugar         | 32       | 32       | 32    |
| Egg           | 60       | 60       | 60    |
| Yeast         | 8        | 8        | 8     |
| **Shortening** | 40      | 40       | 40    |
| Skimmed Milk  | 24       | 24       | 24    |
| Salt          | 6        | 6        | 6     |
| **Bread Improver** | 20      | 20       | 20    |
| Xanthan Gum   | 2        | 2        | 2     |

*) The amount of ingredients was stated in grams.

P1: Bread made from composite flour; P2: Bread made from 100% PFSP flour; P3: Bread made from 100% wheat flour.

2.3. Analysis of bread quality

The bread products were assessed for their physical and chemical quality. Physical evaluation including color (L*, a*, b*, and °Hue value) according to Afshari-Jouybari and Farahnaky [15], Risamasu [16], Simanungkalit and Simanjuntak [17] methods with slight modifications and texture profile using LFRA Texture Analyzer. Chemical evaluation including ash, fat, protein, and dietary fiber contents [18], total sugar [19], and daily energy efficiency.

2.4. Blood glucose measurement

Seven healthy non-diabetic volunteers (males and females) with different ages ranging from 18 to 22 years old, who had normal body mass (BMI = 18.5 to 22.9 kg/m²) and were free from any illness, food allergy, medication, alcohol, and not smoking were recruited in this study. They were requested to maintain a regular diet and activity throughout the experiment. Before participation in this study, all the volunteers were well informed and have written consents. The testing conducted for 10 days in total. During testing, the subjects suggested not to do severe activity. First day was for reference food (glucose) and continued every three days for bread made from composite flour, PFSP flour and wheat flour respectively. The testing was carried out after obtaining permission in the form of ethical clearance. The ethical clearance approval number is No. 777/KEP/USU/2020.

Three types of bread were taken in this study to assess their GI values and pure glucose as the reference. After 10-12 hours overnight fasting, the subjects were ready to be incorporated with the testing process in the morning. Fasting blood glucose were measured at 0 minutes before consuming the food (both reference food and the test food). For reference food, fifty grams of glucose was dissolved in 200 ml mineral water. Blood glucose measurement was done after consuming the food at 30, 45, 60, 90, and 120 minutes. Blood glucose level was performed by pricking finger using a glucometer (Elvasense).
2.5. **Glycemic index calculation**

The incremental area under curves (IAUC) for the blood glucose level variation during the testing of reference (glucose) and test (bread) foods [20] was calculated in the MSExcel-2016 program. The glycemic index was calculated by taking the variations in blood glucose concentration from baseline throughout each postprandial period. The curve of blood glucose response drawn using the average value of each blood glucose response before and after the food consumption within two hours in a graphic form. The graph obtained with the blood glucose concentration plotted on y-axis and time interval on x-axis respectively. The trapezoidal method was used to determine the IAUC (the area calculated by dividing into several sections bounded by the fasting blood glucose level as the horizontal line and the time period as the vertical line). The percentages of respective areas under the curves was used to calculate the glycemic index of each food [21]. The glycemic index was divided into three categories: low (<55), intermediate (55-69), and high (>70) [12].

2.6. **Data analysis**

The research model used was entirely randomized non-factorial design with 3 types of flour used in bread making as a treatment, namely composite flour from a mixture of PFSP flour, starch and fiber with a ratio 75:5:20 (P1); PFSP flour (P2), and wheat flour (P3).

3. **Results and discussion**

3.1. **Physical quality of bread**

The bread made of PFSP flour have a significant difference in color and texture compared to wheat flour. The bread made of wheat flour (P3) had a lighter color and softer texture. Result on color and texture profile are shown in Table 2.

| Parameter      | P1       | P2       | P3       |
|----------------|----------|----------|----------|
| Color          |          |          |          |
| - L*           | 18.57±0.47c | 36.87±0.91b | 80.50±3.05a |
| - a*           | 10.83±1.69b | 17.30±0.82a | 7.53±0.31c  |
| - b*           | -1.93±0.06b | -4.03±0.06c | 20.30±0.30a |
| - °hue         | 10.69±2.01b | 13.11±0.69b | 68.96±3.39a |
| Texture profile|          |          |          |
| - % deformation| 58.70±3.85a | 49.29±1.41b | 50.76±2.60b |
| - Hardness     | 402.67±18.82a | 241.00±12.38b | 100.50±3.97c |
| - Adhesiveness | -93.78±4.98c | -61.27±5.14b | -6.12±2.08a  |

P1: Bread made from composite flour; P2: Bread made from 100% PFSP flour; P3: Bread made from 100% wheat flour. Mean value ± standard deviation (n=3); different letters in row indicate significant differences at p<0.05.

The data in Table 2 showed that differences in flour types had a very significant effect on color and texture profile. P1 and P2 has a lower L* value than P3 because anthocyanin contained in PFSP which produce purple color will decrease the brightness, while the P3 is made of wheat flour that did not contain any anthocyanin. L* value is considered as index of lightness [22].

The differences in flour types had a very significant effect on bread a* value. The PFSP bread had higher value because it contained anthocyanin that shows the reddish colors [23] while the wheat bread shows yellowish colors that included in greenish colors in parameter a*. The differences in flour types had a very significant effect on b* value. Table 2 shows the bread that made of wheat flour (P3) presented
the highest values of yellowness (20.30) and the bread made of 100% PFSP flour (P_2) presented the lowest values of blueness (-4.03) while the bread made of composite flour (P_1) presented the bluish color (-1.93) is higher than P_2 and lower than P_3. For yellowish hues, the parameter b* takes positive value, while for bluish hues it takes negative or lower value [23].

Table 2 shows the differences in flour types had a very significant effect (p<0.01) on °hue. Bread made of wheat flour (P_3) had a higher hue angle that refers to yellowish color and the bread made of PFSP flour (P_2) and composite flour (P_1) had lower hue angle refers to reddish color [22]. As shown in Table 2, bread prepared with the composite flour is the highest in % deformation with 58.70% while bread prepared with PFSP flour and wheat flour are 49.29 and 50.76% respectively. The % deformation is the proportion of the change in shape from the original shape after receiving force. It also refers to product hardness, harder object will have higher % deformation because an object with hard texture will be difficult to transform the shape [24].

The hardest bread is made from composite flour (P_1) with hardness value 402.67 g because of PFSP fiber flour addition in the making will increase the fiber content resulting bread with tougher texture compare to bread made from PFSP flour (P_2) and wheat flour (P_3) which is much lower in fiber content [26]. Bread that high in gluten (P_3) when heated will resulting adhesive effect. While P_1 is the lowest in adhesiveness because did not contain gluten and compare to P_2 which has higher level of starch content will have higher adhesion. Adhesiveness level depends on starch content in the food, that indicates the higher starch content will increase the adhesiveness, vice versa [27].

### 3.2. Chemical quality of bread

Bread made of PFSP flour (P_1 and P_2) contained higher level ash, fat, dietary fiber, and total sugar than bread made of wheat flour (P_3). Result on ash, protein, fat, dietary fiber, total sugar content, and daily energy sufficiency are shown in Table 3.

| Parameter           | P1       | P2       | P3       |
|---------------------|----------|----------|----------|
| Ash content (%)     | 3.41±0.14^a | 3.39±0.12^a | 2.30±0.13^b |
| Protein content (%) | 6.94±0.13^b | 7.28±0.37^b | 13.49±0.39^a |
| Fat content (%)     | 9.09±0.22^b | 13.84±2.83^a | 8.59±1.62^b |
| Dietary fiber content (%) | 15.32±0.91^a | 16.18±1.38^a | 9.45±0.29^b |
| Total sugar (%)     | 6.77±0.32^a | 7.28±0.37^a | 5.38±0.56^b |
| Daily energy sufficiency (%)* | 9.91±0.41^a | 11.06±1.34^a | 11.37±0.31^a |

*aDaily energy sufficiency mean contains certain percentage of energy from the daily energy needs (2150kcal).

P_1: Bread made from composite flour ; P_2: Bread made from 100% PFSP flour ; P_3: Bread made from 100% wheat flour. Mean value ± standard deviation (n=3); different letters in a row indicate significant differences at p<0.05.

The level of ash is significantly affected by the type of flour in bread making. High level of ash in bread can occur due to processing and minerals in PFSP flour. The mineral compounds that found in PFSP was Ca, Zn and Fe [28]. The highest protein content was found in bread made from wheat flour (P_3). Bread with wheat flour as the raw material contained more protein than the one with purple sweet potato. It was because the protein level of wheat flour is 11-12.5% while the purple sweet potato flour protein level is 4% [29]. A significant influence (p<0.05) was given by the type of flour on bread fat content. Purple sweet potato flour quantity will affect the fat content of food products, which is the greater amount added could increase the fat content [30].

Bread made from PFSP flour contained 16.18% of dietary fiber was the highest compared to bread made from composite flour and wheat flour which contained 15.32% and 9.45% respectively. It is due...
to PFSP is highly contained dietary fiber, as high carbohydrates diet that functioning as dietary fiber so that PFSP had a low glycemic index and able to reduce blood glucose level [31].

Total sugars in bread made from composite flour and PFSP flour are 6.77 and 7.28% and significantly higher from bread made of wheat flour with 5.38 %. Baking treatment in bread making will increase the product sweetness because it facilitates the breakage of hydrolytic bonds that maintaining the affiliation of starch granule and other compounds. The condition will elevate the amylase activity in starch degradation and producing sugars. Total sugars content depends on amylase activity, cooking method and initial sugar concentration [33]. The dietary energy sufficiency of the breads was not significantly affected by the flour types. The bread made from composite flour, PFSP flour, and wheat flour fulfill 9.91, 11.06, and 11.37 quantity of daily sufficiency energy respectively.

3.3. Glycemic index of bread
Seven healthy volunteer (three males and four females) participated in the research. The volunteers will be given reference food and tests food and consume it as soon it is served. Blood glucose level were measured before meal (0 minutes), and after meal (30, 45, 60, 90, and 120 minutes). The blood glucose level fluctuation of reference food (glucose) and test foods (bread types) after 2 hours consumption are presented in Figure 1.

![Figure 1. Blood glucose level curve after reference and test food consumption (P1: Bread made from composite flour; P2: Bread made from 100% PFSP flour; P3: Bread made from 100% wheat flour).](image)

The blood glucose response after glucose and test food consumption reached a glycemic climax at 60 and 30 minutes respectively. After 90 minutes consuming test foods, the blood glucose level were close to the fasting glucose level. It shows that the test foods digestibility are lower than glucose which give an effect on low increase in blood glucose level.

The blood glucose response after consuming P1 and P2 are the lowest because it is high in anthocyanin while P1 do not. Purple sweet potato possess anthocyanin pigment as the native antioxidant, also high in carbohydrates but had a low glycemic index. It is suitable for diabetic because able to prevent insulin retention and protect pancreas β-cell from oxidative stress [34].

The glycemic index of reference food and test foods are shown in Table 4 below. The glycemic index is affected by the products physicochemical characteristic. Besides, the individual ability to digest is the important role to define various ranges of glycemic index [35].
Table 4. Glycemic index of reference and test foods.

| Test food       | Glycemic index | GI Class |
|-----------------|----------------|----------|
| Glucose         | 100            | High     |
| P₁              | 41.2           | Low      |
| P₂              | 42.1           | Low      |
| P₃              | 46.3           | Low      |

P₁: Bread made from composite flour; P₂: Bread made from 100% PFSP flour; P₃: Bread made from 100% wheat flour.

Table 4 indicates the GI values of test foods and were classified as low glycemic index diet. The lowest GI was observed to be 41.2 in composite flours bread (P₁) and the highest was 46.3. Adding fiber flour will increase the crude fiber content in bread (P₁) and it will slow the digestion rate because of the product density increases while in the gastrointestinal tract, resulting low glycemic response [36]. Food with low glycemic index could be the diet solution for diabetics. It will break down slowly to release glucose into the bloodstream that cause the lower blood glucose level. On the other hand, foods with high glycemic index are rapidly digested that causing the rapid increase of glucose concentration in blood [37]. This study showed the wheat bread (P₃) was also classified as low glycemic index diet which could happen with the high protein and carbohydrates content. The consumption of high carbohydrates and protein diet provoke the insulin secretion and lowered blood glucose response [38]. The three kinds of bread were classified as low glycemic index food. But the composite flour and PFSP flour bread contained high dietary fiber compared to wheat flour. The daily dietary fiber value average of P₁ and P₂ are 52% which is higher than P₃ with 31%. This can be an option to choose PFSP bread as the high fiber diet that has good benefits for gastronomical.

4. Conclusions

Purple sweet potato processing was able to minimize the use of wheat flour in bread making. The purple sweet potato breads were classified as the low glycemic index food, high in fiber, contained anthocyanin, and good for controlling blood glucose level. Moreover, bread made from composite flour are beneficial for diabetics due to the lowest glycemic index and also for normal individuals due to the nutrition. The classification and recognition of the bread kinds in this study as low GI would help consumers choose flours and breads with low glycemic response, thereby lowering or resisting the development of diabetes. The GI value depends on the fat, protein, carbohydrates, and fiber content.

Acknowledgement

The research was supported by Directorate General of Research Strengthening and Development, Ministry of Research, Technology and Higher Education Repubic of Indonesia through “Penelitian Terapan 2020” project.

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