Physicochemical and sensory characteristics of bread made from flour, starch and solid waste flour of purple sweet potatoes

M A Valino¹, E Julianti¹,²* and H Sinaga¹

¹Department of Food Science, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia.
²Centre for Tubers and Roots Crop Study, Faculty of Agriculture, Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia.

E-mail: *elisa1@usu.ac.id

Abstract. Purple sweet potato (PSP) is one of many agricultural commodities grown in Indonesia. However, its processing in increasing economic value is still very little done. In the PSP starch processing will be produced the fibre rich solid waste which is unutilized yet. The purpose of this research is to study the physicochemical and sensory characteristics of bread produced from PSP flour, PSP starch, and flour from solid waste of PSP starch processing (SWF) in various ratio namely: 100:0:0; 90:10:0; 90:5:5; 90:10:0; 80:0:20; 80:15:5; 80:10:10; and also bread from 100% wheat flour as control. The results showed a ratio of flour, starch, and solid waste flour provide a significant effect on the value of L, browning index, specific volume, hardness, % deformation, adhesiveness, gumminess, chewiness, anthocyanin levels and sensory characteristics. Bread made from 100% PSP flour had the best quality and can be accepted by consumers.

1. Introduction
Purple sweet potato (PSP) is one type of sweet potato in addition to the white sweet potato, orange, and yellow [1]. The purple colour of sweet potato tuber is caused by the presence of anthocyanin pigments. The content of anthocyanins in PSP is almost equivalent to other fruits such as blueberries, blackberries, cranberries, and grapes [2]. Anthocyanins in PSP, among others cyanidin, pelargonidin, peonidin, and malvidin [3]. In Japan PSP developed contained 0.4-0.6 mg anthocyanins/g [4]. PSP anthocyanin has a high antioxidant activity [5] and can be used as a source of food colorant with high stability [6]. PSP is also rich in carbohydrates in the form of starch. PSP contains a starch and amylose of 98.78% and 19.74% respectively [7].

Besides processed into flour, PSP can also be processed into starch. In the PSP starch processing will produce solid waste which is rich in fibre. PSP fibre is a soluble fibre that can bind with bile acid and inhibit synthesis of cholesterol [8,9]. It makes PSP has the potential to use as functional food ingredient such as to replace wheat flour in bread making [10], noodles [11], cookies [12], and cakes [13,14]. Bread is one of the flour-based products favoured by the people of Indonesia. This can be seen from the presentation of sweet bread consumption increased from 2.579,2 kg/capita/year in 2014 to 5.849,8 kg/capita/year in 2018 [15]. The objective of this study was to evaluate the effect of ratio of flour, starch and flour from solid waste of PSP starch processing in bread making.
2. Materials and methods
Purple sweet potato used was purchased from farmers in Phak Phak Barat North Sumatera with optimal maturity level characterized by dark purple colour in tuber fleshed. Ingredients in bread making were bread improver, salt, sugar, yeast, shortening, full cream milk, eggs, and xanthan gum which were purchased from market in Medan, Indonesia.

2.1. Preparation of PSP flour, starch, and solid waste flour
The making of sweet potato flour is done by sorting, peeled, washed, sliced with a thickness of 2 mm, and soaked in 2000 ppm sodium metabisulphite solution for 15 minutes. The sweet potato chips are washed with tap water and then drained. Sweet potato chips are dried using a drying oven at 55°C for 12 hours, mashed using a hammer mill, sieved with an 80mesh by using sieve machine and then packed in polyethylene plastic bags before use.

Sweet potato starch extraction process is done by sorting, peeled, washed, shredded by using mechanic grater, and soaked in 2000 ppm sodium metabisulphite solution in a ratio of 1: 3, then squeezed and filtered. The pulp consists of PSP solid waste which is rich in fibre then was dried in oven at 60°C, fined with a disc mill and sieved with a size of 80 mesh mechanical sieve, so will obtained PSP solid waste (SWP) which is rich in fibre. The filtrate is settled for 3 hours. Starch sediment was dried using a drying oven at 50°C for 12 hours. The dried PSP starch then was mashed using a blender, sieved with an 80mesh sieve by using sieve machine and then packed in polyethylene plastic bags before use.

2.2. Preparation of bread from PSP flour, starch, and solid waste flour
Bread making is done by mixing PSP flour, PSP starch and SWF in various ratio namely 100:0:0 (control 1), 90: 10: 0; 90: 5: 5; 90: 0: 10; 80: 0: 20; 80: 15: 5; 80:10:10. The total of composite flour used in bread making was 100 g. Other ingredient such as 30 g sugar, 2 g instant yeast, 1.5 g salt, 5 g bread improver, and 1.5 g xanthan gum were added to the composite flour and then stirred using a low speed mixer until homogenous, and then 30 g eggs and 60 g liquid full cream milk were added and stirred with a mixer to form a mixture. 10 g shortening was added while still stirring until smooth dough was formed. The dough then was weighed and divided by a weight of 50 g each and formed a circle. Each piece of bread dough was put into a baking sheet and rest for 30 minutes, baked in oven at 165 °C for 25 minutes, cooled to room temperature for 30 minutes, and packaged in polyethylene plastic bags before analysis. Bread makes from 100% wheat flour without adding of eggs and xanthan gum was prepared in the same process as PSP bread.

2.3. Analysis of PSP bread quality
Resulting PSP bread were analysed for their colour (L*, a* and b* value) by using a Minolta Chromameter CR-400 (Minolta Camera Co., Ltd., Tokyo, Japan). The value of °Hue and browning index were calculated according to Hutchings [16] and Jimenez et al. [17] respectively as following equation:

\[ \theta \text{Hue} = \tan^{-1}\left(\frac{b}{a}\right) \]  

\[ \text{Browning Index} = \left[100 \left(x-0.31\right)\right] / 0.172, \text{and } x = \left(a + 1.75L^*\right) / \left(5.645L^* + a^* - 3.01b^*\right) \]  

Specific volume of bread was determined by using seed displacement test [18]. Texture measurements are carried out using Texture Analyser (TA-XT 21, Japan) and texture parameter tested included adhesiveness, %deformation, hardness, cohesiveness, chewiness, gumminess, and springiness. Anthocyanin content of PSP bread was determined as of Giusti and Wrostad method [18], while crude fibre was determined by using AOAC method [19]. The sensory properties of PSP breads were evaluated by using 70 inexperienced individual panel members both genders and 5 sensory attributes were tested namely colour, aroma, taste, texture, and overall acceptability. The sensory
analysé using 7 point of scale (1=dislike extremely, 2=dislike, 3=rather dislike, 4=neither like nor dislike, 5=rather like, 6=like, 7=like extremely)

2.4. Data analysis
Experiments were performed by using a randomized completely design using SPSS ver.22 for windows. All observed parameters were analysed in triplicate then averaged and reported in Tables. The statistical analysis was done using one-way analysis of variance (ANOVA) procedures. Samples with statistical different were determined the difference of mean values by using least Significant Ranges (LSR) method at p<0.05.

3. Results and discussion

3.1. Effect of ratio PSP flour, starch and SWF on physicochemical properties of PSP bread
The physicochemical properties of PSP bread as affected by the ratio of PSP flour, PSP starch, and solid waste flour from PSP starch processing were summarized in Table 1, Table 2 and Table 3. Table 1 showed that no significant difference (p>0.05) among the samples in “Hue value, but significant differences (p<0.05) were found in PSP breads as affected by ratio of PSP flour, PSP starch and SWF. Bread made from 100% wheat flour had the highest browning index, due to the higher protein content in wheat flour, while sweet potato as the other tuber crops is low in protein content [20]. Browning index was affected by protein and reducing sugars content in food products, since they can promote the Maillard reaction and resulting the higher value of browning index [21].

Table 1. The effect of PSP flour, PSP starch and solid waste flour of PSP starch processing on colour and specific volum of PSP breads

| Treatment | “Hue” | Browning Index | Specific Volume (ml/g) |
|-----------|-------|----------------|------------------------|
| P_1       | 2.71±0.10 | 24.93±2.28^a   | 1.02±0.06^f           |
| P_2       | 2.74±0.04 | 23.28±0.16b    | 1.13±0.08^ef          |
| P_3       | 2.66±0.08 | 24.13±0.75^ab  | 1.22±0.04^e           |
| P_4       | 2.69±0.23 | 25.09±0.91^a   | 1.39±0.07^d           |
| P_5       | 2.82±0.11 | 22.04±1.03^b   | 1.54±0.06^c           |
| P_6       | 2.70±0.17 | 22.42±0.81^b   | 1.63±0.06^nc          |
| P_7       | 2.77±0.25 | 23.18±0.36^ab  | 1.73±0.10^b           |
| P_8       | 69.38±0.78 | 129.61±2.74   | 2.73±0.06^a           |

Ratio of PSP Flour: PSP Starch: SFF = 100:0:0 (P_1), 90:10:0 (P_2), 90:5:5 (P_3), 90:0:10 (P_4), 80:0:20 (P_5), 80:15:5 (P_6), 80:10:10 (P_7), and P_8 = 100% wheat flour. Data consists of 3 replications and ± indicates the standard deviation. Number followed by different letters on the same line differences are significantly different at the 5% level. “Hue and browning index of P_8 sample were not observed since its colour is different with PSP bread.

Based on the research result in Table 1, the specific volume of bread is influenced by the ratio of PSP flour, PSP starch and SWF. The highest specific volume was found in wheat flour bread, and the lowest is found in bread made from 100% PSP flour. Gluten in wheat flour serves as trapping gases of fermentation so that the dough becomes firm and expands [22]. The addition of non-wheat flour would decrease the bread volume, thereby lowering its specific volume [23]. The addition of sweet potato flour is proportional to the amount of fibre that can lower of bread volume, because the fibre can reduce the ability of dough to trap air [24].

Table 2 showed that anthocyanin content of breads was influenced by the amount of the ratio of PSP flour, PSP starch and SWF (p<0.05). Bread made from 100% PSP flour had a highest anthocyanin content, and the addition of starch and fibre (SWF) will reduce the anthocyanin content of
bread. Sweet potato with purple colour of tuber is rich in anthocyanin [25]. Table 2 showed that the highest crude fibre is found in bread made from 100% PSP flour. The addition of starch and solid waste flour from PSP starch processing will decrease the crude fibre content. Bread made from 100% wheat flour had the lowest crude fibre content. Oluwana et al. [26] also obtained the similar result where bread made from composite with more sweet potato flour had a higher fibre content than bread made from more wheat flour.

Table 2. The effect of PSP flour, PSP starch and solid waste flour of PSP starch processing on chemical properties of PSP breads

| Treatment | Anthocyanins Content (ppm) | Crude Fibre (%) |
|-----------|---------------------------|-----------------|
| P1        | 30.03 ± 0.27a             | 4.00 ± 0.18     |
| P2        | 26.29 ± 0.27b             | 3.80 ± 0.11     |
| P3        | 26.78 ± 0.17b             | 3.86 ± 0.02     |
| P4        | 27.12 ± 0.55b             | 3.90 ± 0.14     |
| P5        | 27.12 ± 0.55b             | 3.90 ± 0.14     |
| P6        | 26.05 ± 0.36b             | 3.69 ± 0.12     |
| P7        | 26.49 ± 1.06b             | 3.74 ± 0.14     |
| P8        | 26.05 ± 0.36b             | 3.69 ± 0.12     |

Ratio of PSP Flour: PSP Starch: SFF = 100:0:0 (P1), 90:10:0 (P2), 90:5:5 (P3), 90:0:10 (P4), 80:0:20 (P5), 80:15:5 (P6), 80:10:10 (P7), and P8 = 100% wheat flour. Data consists of 3 replications and ± indicates the standard deviation. Number followed by different letters on the same line differences are significantly different at the 5% level. Anthocyanin content of P8 sample was not observed. no=not observed

Adhesiveness of bread is influenced by the ratio of PSP flour, PSP starch and SWF (p<0.01) in the manufacture of bread. Adhesiveness indicates the sticky properties of bread which is shown in negative values of this parameter [27]. Table 3 showed that P3 and P4 which had the best adhesiveness are those containing 90% PSP flour.

Table 3 also showed there were significant differences (p<0.05) in % deformation of PSP breads as affected the ratio of PSP flour, PSP starch and SWF. % Deformation can be defined as the percentage of a given amount of compressive force until there is a change from earlier forms. The lowest % deformation was found in wheat flour bread (P8), but there was no significant difference between P8, P1 and P4 samples. The lower % deformation in P3, P4 and P8 samples is related to their softer texture which resulted from their porosity [28].

Table 3. The effect of PSP flour, PSP starch and solid waste flour of PSP starch processing on adhesiveness, % deformation and hardness of PSP breads

| Treatment | Adhesiveness | %deformation | Hardness (g) |
|-----------|--------------|--------------|--------------|
| P1        | -1059.58±162.33a | 48.96±1.36a | 727.50±60.81b |
| P2        | -2100.15±89.93b  | 41.36±0.23bc | 715.75±13.08b |
| P3        | -942.06±76.24a   | 40.76±0.15d  | 643.00±59.40b |
| P4        | -926.16±103.18a  | 39.75±0.18d  | 863.25±68.24a |
| P5        | -1017.87±34.52a  | 42.33±0.02b  | 648.25±25.10b |
| P6        | -3082.38±579.67c | 41.61±0.64bc | 904.25±0.35a  |
| P7        | -2359.06±115.59b | 41.27±0.08bc | 948.00±41.72a |
| P8        | -1047.12±154.01a | 38.62±0.35d  | 778.75±56.21b |

Ratio of PSP Flour: PSP Starch: SFF = 100:0:0 (P1), 90:10:0 (P2), 90:5:5 (P3), 90:0:10 (P4), 80:0:20 (P5), 80:15:5 (P6), 80:10:10 (P7), and P8 = 100% wheat flour. Data consists of 3 replications and ± indicates the standard deviation. Number followed by different letters on the same line differences are significantly different at the 5% level.
Table 4 showed PSP bread hardness ranged from 643.00 to 948.00 N, and the highest hardness value was found in P7 sample, while the lowest one was in P3 sample. The presence of fibre in the PSP starch and SWF causes the dough has a strong adhesiveness and the texture becomes hard [29].

**Table 4.** The effect of PSP flour, PSP starch and solid waste flour of PSP starch processing on cohesiveness, chewiness, gumminess, and springiness of PSP breads

| Treatment | Cohesiveness | Chewiness | Gumminess | Springiness |
|-----------|--------------|-----------|-----------|-------------|
| P1        | 0.26±0.01    | 1940.67±31.05<sup>bc</sup> | 185.56±6.60<sup>b</sup> | 10.16±0.98  |
| P2        | 0.24±0.01    | 2547.89±306.79<sup>b</sup> | 199.47±8.61<sup>b</sup> | 13.27±0.26  |
| P3        | 0.24±0.00    | 1910.69±115.05<sup>bc</sup> | 155.69±16.96<sup>cd</sup> | 12.31±0.60  |
| P4        | 0.21±0.01    | 1428.17±31.42<sup>c</sup> | 181.56±1.80<sup>bc</sup> | 8.41±0.12   |
| P5        | 0.24±0.03    | 1334.19±55.83<sup>c</sup> | 135.66±8.01<sup>d</sup> | 9.84±0.17   |
| P6        | 0.29±0.04    | 3688.73±294.45<sup>a</sup> | 287.65±4.26<sup>a</sup> | 12.80±0.83  |
| P7        | 0.24±0.03    | 3450.29±523.20<sup>a</sup> | 284.45±19.47<sup>a</sup> | 12.10±1.01  |
| P8        | 0.23±0.01    | 1611.70±203.82 | 172.17±1.87<sup>c</sup> | 9.10±0.71   |

Ratio of PSP Flour: PSP Starch: SFF = 100:0:0 (P1), 90:10:0 (P2), 90:5:5 (P3), 90:0:10 (P4), 80:0:20 (P5), 80:15:5 (P6), 80:10:10 (P7), and P8 = 100% wheat flour. Data consists of 3 replications and ± indicates the standard deviation. Number followed by different letters on the same line differences are significantly different at the 5% level.

Table 4 showed there were no significantly differences (p>0.05) among the bread samples in cohesiveness and springiness, but there were significantly differences (p<0.05) in chewiness and gumminess as affected by ratio of PSP flour, starch and SWF. Cohesiveness is described elastic as behaviour of breads [30] and indicates the strength of bread crumb internal bonds [27], while chewiness indicates hardness behaviour [31].

### 3.2. Effect of ratio of PSP flour, starch and SWF on sensory properties of PSP bread

Table 5 showed the effect of ratio of PSP flour, starch and SWF on sensory properties of PSP breads.

**Table 5.** The effect of ratio of PSP flour, starch and solid waste flour of PSP starch processing on sensory properties of PSP breads

| Treatment | Colour | Aroma | Taste | Texture | Overall Acceptance |
|-----------|--------|-------|-------|---------|--------------------|
| P1        | 5.35±0.24 | 4.97±0.12 | 5.26±0.13 | 5.08±0.05 | 5.16±0.11          |
| P2        | 5.37±0.09 | 5.04±0.32 | 5.05±0.06 | 5.09±0.18 | 5.02±0.18          |
| P3        | 5.11±0.07 | 5.09±0.20 | 5.08±0.13 | 4.81±0.12 | 5.08±0.11          |
| P4        | 5.12±0.10 | 4.83±0.02 | 5.09±0.02 | 4.97±0.21 | 5.01±0.12          |
| P5        | 5.19±0.14 | 4.98±0.12 | 5.09±0.08 | 5.05±0.21 | 5.14±0.04          |
| P6        | 5.03±0.02 | 4.98±0.23 | 5.15±0.13 | 4.97±0.04 | 5.11±0.05          |
| P7        | 5.24±0.13 | 5.08±0.10 | 5.03±0.13 | 5.03±0.07 | 5.03±0.07          |
| P8        | 5.41±0.36 | 5.30±0.26 | 5.30±0.26 | 5.26±0.29 | 5.21±0.17          |

Ratio of PSP Flour: PSP Starch: SFF = 100:0:0 (P1), 90:10:0 (P2), 90:5:5 (P3), 90:0:10 (P4), 80:0:20 (P5), 80:15:5 (P6), 80:10:10 (P7), and P8 = 100% wheat flour. Data consists of 3 replications and ± indicates the standard deviation. Number followed by different letters on the same line differences are significantly different at the 5% level.
The results showed that there were no significantly differences among the bread sample in sensory properties as affected by ratio of PSP flour, starch and SWF. The score of all sensory parameters observed in this research varied from 4-6 which indicates that panellists provide a rating for sensory value of PSP bread between neither likes nor dislikes to likes. There is also no significant different between PSP bread and bread made of 100% wheat flour in sensory properties. This result showed that bread made from 100% PSP flour is more acceptable by panellists than bread made from a mixture of PSP flour, starch, and solid waste flour of PSP starch processing.

4. Conclusion
Ratio of flour, starch and flour of solid waste of purple sweet potato starch processing provides a highly significant effect on the colour, browning index, specific volume, texture, and anthocyanin levels. Bread made from 100% purple sweet potato flour contains a higher anthocyanin and crude fibre content and more acceptable by consumers. Nevertheless, the use of PSP starch and solid waste flour from PSP starch processing in bread making needs to be considered because it can improve the texture of gluten free breads. The utilization of purple sweet potato may help to reduce the use of wheat flour in food application.

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