Effect of purple sweet potato flour substitution and hemicellulose concentration on physical properties of bread

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Abstract. The substitution of purple fleshed sweet potato flour (PSPF) on wheat flour (WF) and the addition of hemicellulose enzyme concentration have been studied for their effect on the physical properties of bread. A factorial completely randomized design was used to perform the research. The first factor was PSPF and WF ratio consists of 0:100; 25:75; 50:50; and 100:0. The second factor was hemicellulose concentration consists of 0%; 0.025%; and 0.05%. The interaction between a ratio of PSPF and WF and hemicellulase concentration produced breads with significantly different (p<0.05) on colour index (L*, a*, b*, O'Hue), specific volume, and organoleptic value of texture. The substitution of 25% PSPF on WF and adding 0.05% hemicellulase enzyme produce bread with the best quality.

1. Introduction
Sweet potato is 6th ranks of world important food commodities [1]. It is very tolerant of high temperatures, infertile and dry soil conditions [2] Sweet potatoes can be used to overcome malnutrition and poverty problems in developing countries, because they contain high carbohydrates, besides that the anthocyanins content and minerals such as Fe and Ca is also an advantage of sweet potatoes. Fresh tubers of sweet potatoes contain carbohydrates as much as 80-90% of the dry basis and 50-80% of them in the form of starch. This carbohydrate content is 50% more than potatoes [3].

Sweet potato with purple fleshed colour was potential to be used as functional food because of its high anthocyanin content, has an attractive colour, and can be used to prevent various types of degenerative diseases [4]. The anthocyanin content in purple sweet potatoes was almost the same as other fruits [5].

Sweet potato, like other tuber products, has a short shelf life because of its high moisture content, so it is easily damaged. Processing sweet potatoes into flour is one way to increase their shelf life. The results of previous research indicate that purple sweet potato flour can be used for bread [6,7], cookies [8], cake [9,10], and noodle [11] products.

The disadvantages of bread made from PSP flour are the low specific volume of the bread and the less preferred texture. This is due to the high fibre content of sweet potatoes. The previous research showed that the use of enzymes such as alpha amylase and hemicellulase can increase the volume of bread, crumb texture and staling properties of bread so that it can be used as an alternative in non-wheat bread processing [12,13]. Hemicellulase enzyme can make a bread dough soft because the enzymes help
introduce more water during the mixing process so it can decrease of specific volume [14]. The quality of bread product as affected by the substitution of WF by PSPF and hemicellulase concentration was evaluated in this study.

2. Materials and methods
Fresh tubers of purple sweet potatoes with a harvest time of 3–4 months after planting and a size of 100-300 g, were obtained from farmers in central market Medan, North Sumatera Province. Hemicellulase enzymes was purchased from CN lab nutrition. Additional ingredients in the PSP flour processing were sodium metabisulfite and distilled water. Other ingredients for making plain bread are shortening, sugar, yeast, skim milk, and salt.

2.1. PSP flour preparation
Fresh purple fleshed sweet potatoes were washed, peeled, dipped in 2% sodium metabisulfite solution for 30 minutes, drained, washed and drained again, and then dried in 50°C of hot air oven for 12 hours, milled by using disc mill, sieved with 60mesh sieving, packed in airtight containers and stored at ambient temperature before using.

2.2. Bread making
Four blends of composite flour were made by mixing homogenously of wheat flour and PSP flour in the percentage ratio: 0:100; 25:75; 50:50, and 100:0. The bread dough was made using the straight dough method. Dry ingredients such as composite flour (400g), instant yeast (8g), sugar (32g), skim milk (24g), and hemicellulose enzyme with various concentration (0%, 0.025%, 0.05%) were mixed using a moderate speed mixer until homogeneous. The water (240 ml) was added gradually while mixed to form the dough, and then salt (6g) and shortening (40g) were added while kneading until a smooth dough [15]. After that it is fermented for 30 minutes at 35°C, then knocked back and put into a well-oiled bread pan, proofed rest at room temperature for 30 minutes, and it was baked in a preheated oven at 200°C for 30 minutes. After baking process, the bread was de-panned immediately and cooled rest at room for 30 minutes, and then it was packed with aluminium foil and stored at ambient temperature before being analysed [16].

2.3. Bread colour determination
Colour of breads crumb and crust were determined using a CR-400 type of Chromameter (Minolta Camera, Japan) to obtained the lightness (L*), redness/greenness (a*), yellowness/blueness (b*), and hue value was obtained from tan(b/a). The browning index of breads crust and crumb was obtained using the equation from Jimmenez et al. [17], as follows:

\[ BI = \frac{100 \times (x - 0.31)}{0.17} , \text{where} \ x = \frac{(a^{*} + 1.75L^{*})}{(5.645L^{*} + a^{*} - 3.01b^{*})} \]  

(1)

2.4. Bread specific volume determination
The specific volume of bread shows the bread volume per unit weight (ml/g). The bread volume was determined by using a seed displacement test method [18]. Bread weight was measured using a laboratory scale 30 min after removing it from the oven.

2.5. Organoleptic value of bread texture
The organoleptic value of bread texture was evaluated by 70 panellists by rating each bread sample at a seven-point hedonic scale (1= dislike very much - 7 = like very much) [19]. The score from 70 panellists then were averaged and analysed by ANOVA.

2.6. Data analysis
The factorial completely randomized design was used in this research, with the ratio of PSP flour and wheat flour as the first factor and hemicellulose enzyme concentration as the second factor. The ratio of
PSP flour and wheat flour consists of 4 levels, namely 0:100; 25:75; 50:50; and 100:0. Hemicellulose enzyme concentration consists of 3 levels, namely 0; 0.025’ and 0.05%. The treatment combination of bread formulation was 4 x 3 = 12 treatments, and each treatment was made on 3 replications, so that the total number of bread samples was 36 samples. Each parameter of bread quality was measured in triplicate also, and statistically analysed using SPSS. The means of data were compared using multiple range test by Duncan (DMRT) at a probability level of 5% (p<0.05).

3. Results and discussion

3.1. Colour index

Table 1 and Table 2 summarized the mean of the breads crust and crumb as affected by ratio of PSPF and WF and hemicellulase concentration.

Table 1. The crust colour of bread as affected by ratio of PSPF and WF and hemicellulase concentration

| Ratio of PSPF : WF (P) | Enzyme Concentration (E) | L*          | Crust Colour Index a* | b* | a°Hue |
|-----------------------|--------------------------|-------------|-----------------------|----|-------|
| P₁ = 0:100            | E₁ = 0 %                 | 62.98±1.34  | 20.81±0.34           | 36.12±0.80 | 20.02±0.66 |
|                       | E₂ = 0.025%              | 59.77±0.45  | 20.37±0.49           | 36.47±0.34 | 20.27±0.38 |
|                       | E₃ = 0.05%               | 61.09±0.56  | 20.10±0.35           | 35.95±0.96 | 20.26±0.37 |
| P₂ =25:75             | E₁ = 0 %                 | 45.22±0.55  | 16.99±0.93           | 20.40±0.01 | 50.29±1.53 |
|                       | E₂ = 0.025%              | 44.71±0.45  | 16.30±0.15           | 20.25±0.51 | 51.16±0.56 |
|                       | E₃ = 0.05%               | 45.62±0.29  | 16.14±0.18           | 20.43±0.02 | 51.69±0.29 |
| P₃ = 50:50            | E₁ = 0 %                 | 38.28±0.57  | 16.29±0.19           | -2.38±0.13 | 8.21±0.60  |
|                       | E₂ = 0.025%              | 38.55±1.00  | 16.15±0.23           | -2.41±0.16 | 8.33±0.43  |
|                       | E₃ = 0.05%               | 37.37±0.54  | 15.83±0.34           | -2.52±0.05 | 9.05±0.11  |
| P₄ =100:0             | E₁ = 0 %                 | 26.50±1.31  | 10.11±0.30           | -5.41±0.21 | 28.16±0.61 |
|                       | E₂ = 0.025%              | 25.13±0.37  | 10.67±0.38           | -5.44±0.12 | 27.02±1.04 |
|                       | E₃ = 0.05%               | 24.79±0.87  | 10.50±0.09           | -5.40±0.15 | 27.21±0.78 |

Mean values ± standard deviations in the same column with different superscripts are different significantly by DMRT tests (p<0.05).

Table 2. The crumb colour of bread as affected by ratio of PSPF and WF and hemicellulase concentration

| Ratio of PSPF : WF (P) | Enzyme Concentration (E) | L*          | Crumb Colour Index a* | b* | a°Hue |
|-----------------------|--------------------------|-------------|-----------------------|----|-------|
| P₁ = 0:100            | E₁ = 0 %                 | 64.69±0.52  | 20.64±0.23           | 35.06±1.09 | 19.83±1.03 |
|                       | E₂ = 0.025%              | 64.63±0.17  | 20.16±0.40           | 32.99±0.95 | 19.52±1.21 |
|                       | E₃ = 0.05%               | 64.61±0.73  | 20.67±0.66           | 19.40±0.52 | 33.34±0.47 |
| P₂ =25:75             | E₁ = 0 %                 | 43.51±1.11  | 17.44±0.04           | 21.46±0.75 | 50.88±1.03 |
|                       | E₂ = 0.025%              | 45.55±0.18  | 17.40±0.07           | 21.05±0.45 | 50.41±0.48 |
|                       | E₃ = 0.05%               | 44.33±0.72  | 17.08±0.44           | 21.12±0.32 | 51.03±0.59 |
| P₃ = 50:50            | E₁ = 0 %                 | 38.80±0.59  | 16.45±0.95           | -3.07±0.27 | 10.57±0.95 |
|                       | E₂ = 0.025%              | 38.78±0.40  | 17.09±0.62           | -3.11±0.22 | 10.30±0.48 |
|                       | E₃ = 0.05%               | 38.85±0.51  | 16.84±0.11           | -3.02±0.50 | 10.16±1.70 |
| P₄ =100:0             | E₁ = 0 %                 | 26.42±0.66  | 11.90±0.65           | -6.05±0.22 | 26.99±1.92 |
|                       | E₂ = 0.025%              | 27.68±0.15  | 11.09±0.69           | -6.20±0.24 | 29.25±1.63 |
|                       | E₃ = 0.05%               | 26.69±0.72  | 11.46±0.73           | -6.08±0.20 | 28.00±1.87 |

Mean values ± standard deviations in the same column with different superscripts are different significantly by DMRT tests (p<0.05).
The colour index (L*, a*, b*) of bread crust made from 100% PSPF and composite flour were significantly lower than that in bread from 100% WF, but the *hue value of bread made from 100% WF was significantly lower than those in 100% PSPF and composite flour breads (Figure 1). Hemicellulase concentration and the interaction between ratio of PSPF and WF and hemicellulase concentration did not affect the colour index of breads crust. The same results were obtained for the colour index of bread crumb. The presence of PSP flour resulted a darker breast crust and crumb. The changes of bread colour both in crust and crumb is related to the increased concentration of reducing sugars that found in PSP flour, which promoted the Maillard reaction. This reaction will cause a browner colour of bread [20].

The dark crust and crumb colour with the addition of PSP flour (Table 1 and Table 2) associated with anthocyanin pigment which cause purple colour in PSP flour [21,22]. The higher value of a* (positive) indicating the colour will become reddish, while the lower (negative) one indicates a greenish colour [23]. Wheat is a flour made from wheat kernels. Wheat contains carotenoid pigments that produce a yellowish [24].

The increasing of PSPF in the bread making will significantly decrease (p<0.05) the b* value in bread. The b* value indicates colours ranging from blue to yellow. The lower b* value (negative) indicates a darker blue colour and a* high b* value (positive) indicates a darker yellow colour [23].

Table 1 and 2 show the addition of PSP flour will decrease significantly (p<0.05) the lightness level of bread. The similar results were obtained from previous research [14]. At the same flour ratio, the difference in hemicellulose enzyme concentration did not have a different effect on the L* value of bread.

The value of *Hue of bread crust fluctuates due to the use of different flours, namely PSP flour which contains anthocyanin pigments while wheat flour does not contain anthocyanin. Anthocyanin pigments are pigments that cause almost all colours blue, purple, red [23].

3.2. Browning index
The browning index of bread was affected significantly (p<0.05) by the ratio of PSPF and WF, but was not affected (p>0.05) by hemicellulase concentration and the interaction between ratio of PSPF and WF and hemicellulase concentration.

![Figure 1](image_url). The browning index of bread as affected by PSPF : WF ratio.

Figure 1 shows that a significantly highest (p<0.05) browning index value of bread made from 100% PSPF. The increasing of browning index was related to the increasing of reducing sugars in PSP flour which promote the Maillard reaction and produces a compound, namely melanoidin [25].

3.3. Specific volume of bread
The specific volume of breads was significantly affected (p<0.05) by the interaction between PSPF and WF ratio and hemicellulase concentration (Figure 2). The more PSPF will decrease the specific volume
of bread, but at the same ratio of PSPF and WF, the more hemicellulase enzyme the higher specific volume of bread will be obtained. This could be due to the reduced of gluten content in the dough resulting in an increase in the weight of the bread while the volume decreases [26].

![Figure 2](image_url)  

**Figure 2.** The specific volume of bread as affected by the interaction between PSPF and WF ratio and hemicellulase concentration.

3.4. *Organoleptic value of texture*

The organoleptic texture value of bread was only affected by the PSPF and WF ratio but not by hemicellulase concentration (Table 3).

**Table 3.** The organoleptic texture value of bread as affected by PSPF and WF ratio and hemicellulase concentration

| Ratio of PSP Flour: Wheat Flour (P) | Enzyme Concentration (E) | Organoleptic Value of Texture |
|------------------------------------|--------------------------|--------------------------------|
| P₁ 0%:100%                         | E₁=0 %                   | 5.83±0.05a                    |
|                                    | E₂=0.025%                | 5.60±0.19a                    |
|                                    | E₃=0.05%                 | 5.74±0.38a                    |
| P₂ 25:75                           | E₁=0 %                   | 5.47±0.14b                    |
|                                    | E₂=0.025%                | 5.32±0.32b                    |
|                                    | E₃=0.05%                 | 5.47±0.30b                    |
| P₃ 50:50                           | E₁=0 %                   | 5.13±0.18b                    |
|                                    | E₂=0.025%                | 5.05±0.28b                    |
|                                    | E₃=0.05%                 | 5.48±0.17b                    |
| P₄ 100:0                           | E₁=0 %                   | 4.84±0.28c                    |
|                                    | E₂=0.025%                | 4.79±0.30c                    |
|                                    | E₃=0.05%                 | 4.92±0.36c                    |

Mean values ± standard deviations in the same column with different superscripts are different significantly by DMRT tests (p<0.05).

The increasing of PSPF will decrease the organoleptic value of the bread texture due to the harder texture with the increasing of PSP flour. The increasing of bread hardness is due to the lack of gluten content with the increasing amount of PSP flour and causes the decrease of dough's ability to trap CO₂ gas during the fermentation process [27].
4. Conclusions
Wheat flour substitution with purple sweet potato flour will produced a purple colour of bread due to the anthocyanin content of PSP flour. However, it also results in lower specific volume of bread and making the bread making from PSP flour is inferior than bread made from wheat flour. The addition of hemicellulase enzyme will increase the specific volume and organoleptic value of texture of the resultant bread. The ratio of purple sweet potato and wheat flour of 25:75 and the addition of 0.05% hemicellulase enzyme produced the best quality of bread.

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