Heat-Moisture Treatment to Sweet Potato (*Ipomoea batatas* L.) Flour Increased Volume Expansion and Other Characteristics of Pan Bread Prepared with Wheat flour Partially Substituted

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Abstract Bread including pan bread as staple food is one of the most consumed foodstuffs worldwide. To reduce, however, wheat flour utilization from imported wheat, pan bread was partially substituted with modified sweet-potato flour. The objectives of this research were to determine effect of heat moisture treatment (HMT) temperature and time on sweet-potato flour swelling power, solubility, and lightness then to select the best treatment, and effect of wheat flour to modified sweet-potato flour ratios on pan-bread physicochemical and organoleptic characteristics. Sweet-potato flour was modified using HMT (77, 85, 93°C; 3, 6, 9h). In formulations, wheat flour to modified sweet-potato flour ratios were 100:0; 95:5; 90:10; 85:15; 80:20; 75:25; 70:30. Flour treated at 77°C, 3h exhibited the highest swelling power (13.77±0.02g/g) then used for bread making, where pan breads (95:5, 90:10 and 85:15 ratios) were selected due to similarity to control’s physical and organoleptic properties. Pan bread (95:5 ratio) was selected due to similar protein content to pan-bread control; pan breads (95:5 and 90:10 ratios) selected due to their higher volume than control’s with comparable moisture, fat, protein, ash, and carbohydrate contents. Taken together, partial substitution of wheat flour with HMT-treated sweet-potato flour improved volume and other characteristics of pan bread.

Keywords: pan-bread, heat-moisture-treatment, wheat-flour, sweet-potato.

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Introduction

Bread is one of staple food that is consumed a lot by people around the world [1]. Pan bread is mostly consumed by people due to its relatively cheap price, therefore pan bread is reachable to every kind of society thus the consumption of bread is very high [2]. Wheat flour is the main ingredient to make pan bread. However, the problem is that wheat as the raw material for wheat flour is still imported from other countries [3]. Thus, the alternative to reduce the utilization of wheat flour in pan bread making is to develop other commodities that have similar nutritional composition to wheat flour [2]. In this study, sweet potato is used to reduce the utilization of wheat flour in pan bread making.

Sweet potato is one of the highest sources of carbohydrates, thus as energy source, and contains β-carotene, vitamin C, niacin, riboflavin, thiamine, and minerals. However, sweet potatoes in Indonesia are not yet considered as an important commodity despite of the potential and benefits of sweet potato as an alternative food which can improves human nutrition and food security through a food diversification program [4]. The production and productivity of sweet potato in Indonesia continues to increase from year to year, however their utilization and consumption are still limited. In 2018, the total production of sweet potato is 1.914.244 tons with productivity of 180.21 quintal/hectare [5]. However, sweet potatoes are difficult to be stored. Therefore, it can be processed into flour which is less bulky and more stable than the fresh sweet potatoes. However, since the bread is partially substituted with sweet potato flour, its gluten content is reduced, thus modification needs to be done on sweet potato flour to increase its swelling power in order to increase the volume of bread produced. Physical and sensory properties of sweet potato flour are modified physically with High Moisture Treatment (HMT) method. Therefore, incorporation of modified sweet potato flour to pan bread is expected to improve pan bread characteristics and provide high nutritional value, aroma, taste, and texture that are accepted by the consumer.
Materials and methods

Materials used in this research were white sweet potatoes, dried tapioca balls, and wheat flour, modified sweet-potato flour, water, yeast, salt, sugar, bread improver and skim milk powder for pan bread preparation. Other materials used for analyses and assays were of analytical and/or food grades.

Preparation of sweet potato flour

The preliminary stage involved the preparation of sweet potato flour, then the characteristics of the flour produced were observed. The production of sweet potato flour was conducted following the procedures adopted from Ambarsari et al. [6] with modifications. Sweet potatoes (~5 kg) were washed and peeled using a peeler. Then, the peeled sweet potatoes were sliced into thin slices using a slicer. The sliced sweet potatoes were immersed in 0.3% metabisulfite for 15 min to prevent browning. The thin-sliced sweet potatoes were dried on a cabinet dryer at 50°C for 5h. After dried, the sweet potatoes were grinded using a dry blender. Then, they were sieved through an 80-mesh sieve. Characteristics of the sweet potato flour produced were analyzed in terms of yield [7], proximate composition [7], lightness [8], swelling power [9] and solubility analysis [9].

Modification of sweet potato flour

In the main research stage I, sweet potato flour produced was modified using heat moisture treatment (HMT). Modification of sweet potato flour was conducted following the procedures adopted from Fitriani (2014) [10] with modifications. Sweet potato flour (~100 g) was reconstituted with water until its moisture content reached approximately 30%. The amount of water that was needed to be added was calculated by using this equation: 

\[(100\% \ - \ MC1) \times W1 = (100\% \ - \ MC2) \times W2\]

where MC1 is the initial moisture content of flour, whereas MC2 is the desired moisture content of flour, W1 is initial weight of flour and W2 is weight of flour after the addition of water [11]. Then, the reconstituted flour was cooled down at 5°C for 24h. After 24h, the flour was then let alone until reaching room temperature. Then, HMT was done in an oven at different temperature regimes (77, 85, 93°C) and time (3, 6, 9h) in a closed condition wrapped with aluminum foil. The modified sweet potato flour was dried at 50°C for 5h; then grinded and sieved through an 80-mesh sieve. Characteristics of the modified sweet potato flour produced were analyzed including proximate analysis [7], lightness [8], swelling power [9] and solubility analysis [9].

Preparation of pan bread partially substituted with modified sweet-potato flour

In the main research stage II, pan bread was prepared using different ratios of wheat flour and modified sweet-potato flour. Ingredients needed to make the pan bread include flour, water, yeast, salt, sugar, bread improver, skim milk powder and shortening, with the formulation shown in Table 1.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Amount (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100:0</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>53.19</td>
</tr>
<tr>
<td>Modified sweet potato flour</td>
<td>0</td>
</tr>
<tr>
<td>Bread improver</td>
<td>0.27</td>
</tr>
<tr>
<td>Skim milk powder</td>
<td>31.91</td>
</tr>
<tr>
<td>Yeast</td>
<td>1.06</td>
</tr>
<tr>
<td>Salt</td>
<td>0.80</td>
</tr>
<tr>
<td>Shortening</td>
<td>5.32</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: AACC (2000) [12] with modification

The straight dough method was used for the pan bread making process, and the process was adopted from AACC (2000) [13] with...
modifications. All dry ingredients (flour, yeast, salt, sugar, and skim milk powder) were weighed and mixed manually. The mixing process was then continued using a dough mixer for a few minutes. Water was added step by step into the mixed ingredients. All ingredients were then mixed with a mixer under low speed for 2 min, followed by another 2 min of mixing under increased speed. Shortening was then added and mixing was continued until dough was perfectly formed. The dough was rounded into one ball, covered with wet cloth, and left for about 10 min. Then the dough was rounded and covered with wet cloth again for 15 min. Afterwards, the dough was rolled using a wooden roller pin to form thinner dough which will be placed into baking pans. The dough is then left for proofing at 30-35°C and RH of 80-85%, followed by baking in oven with temperatures of 190°C for 25 min. The bread was then taken out from the oven, and let it cool down. The control bread, bread treated with different ratios of wheat flour to modified sweet potato flour were then evaluated in terms of their sensory acceptance, volume, weight, crust and crumb color, and texture.

Proximate analyses of sweet potato flour
Proximate analysis of sweet potato flour was conducted for its moisture content, protein, fat, ash, all based on AOAC (2005) [7] and carbohydrate content calculated by difference. For moisture content, approximately 2 g of sweet potato flour was dried in a 105°C oven for 3-5h and proceeded the rest according to the standard method of AOAC (2005) [7]. Protein content was examined using 2 g of sample according to the Kjeldahl method [7]. Fat content evaluation to 2 g of sample was performed using Soxhlet extraction method [7]. Ash content was determined using the combustion method at 500°C using ~5g samples, following the protocol of AOAC [7]. Finally, the carbohydrate content was calculated using the by-difference method (100 - the sum of moisture content, ash content, protein content, and fat contents) [7].

Flour characteristics
Swelling Power and water solubility were analyzed based on the method of Kusumayanti et al. [9]. Samples of approximately 0.1g were used for each of the analysis. Lightness was measured as described by Nielsen (2010) [8] where the analysis was done using a Konica Minolta CR-400 chromameter (Konica Minolta Sensing Singapore Pte Ltd) with L* value and °Hue as the parameter.

Starch analyses
Total starch content was determined using the acid hydrolysis method described in AOAC (2005) [7]. Sample of approximately 0.5g was used for hydrolysis and proceeded the standard method of AOAC (2005) [7]. Amylose and amylopectin contents were analyzed using the methods of AOAC (2005) [7]. In amylose analysis, approximately 100 mg of samples were used and proceeded the rest based on the method of AOAC (2005) [7]. Amylopectin content was calculated based on total starch content subtracted with the amylose content [7].

Pan bread characteristics
Weight and Volume of pan bread were determined according to Bibiana et al. [14]. The weight of bread was measured by using a balance and the volume was measured by the seed displacement method. Crumb firmness determination [13] was carried out using Texture Analyzer-XT (Stable Micro System, Surrey, UK). Texture profile analysis (TPA) was carried out equipped with 25 kg load cell. The bread sample was sliced in the middle of the loaf to obtain uniform slice of 2 cm thickness. A two cycle of crumb compression test was performed using the series of P/36R aluminum plate probe (test speed 2 mm/s penetration distance 10 mm, post-test speed 2mm/s and trigger load 50 g). The peak force of compression was reported as firmness. Crust and crumb lightness was measured as described by Nielsen (2010) [8] where the analysis was done using a Konica Minolta CR-400 chromameter (Konica Minolta Sensing Singapore Pte Ltd) with L* value and °Hue as the parameter.

Scoring and hedonic tests
Scoring test [15] was done involving 40 untrained panelists evaluating two batches of samples. The panelists were asked to give a score from 1 - 6. The attributes measured were crust color, crumb color, crumb firmness, aroma, taste. Hedonic test [16] was also performed involving 40 untrained panelists two batches of samples. The parameters in this hedonic test were taste, aroma, color, texture, and overall acceptance of pan bread. Forty untrained panelists rated the samples from 1 - 7 of the hedonic scale of likeness.

Statistical Analysis
Statistical analysis was carried out using Completely Randomized Design one and/or two factors conducted using SPSS application program.

Results and discussion
Moisture content of sweet potato, yield, and chemical composition of sweet potato flour
Moisture content of sweet potato obtained from this research was 65.55±0.31% (wb); whereas the moisture content reported was 68.50% (wb) [17]. There are a lot of intrinsic and extrinsic factors that may affect the moisture content of a sample. Different volume, weight, cultivars of sweet potato, cultivation area and different climate can give different moisture content [18] [19].

Yield of sweet potato flour was 74.29±2.75% (db), whereas the yield of sweet potato flour has been reported [20] was 73.5% (db). There are small differences between the yield of sweet potato flour obtained from the research with the report. Several extrinsic and intrinsic factors can affect the yield of sweet potato flour.

Chemical composition of sweet potato flour produced in this research is shown in Table 2. According to Akbar [18], the different composition obtained from this research with literature was due to variation of cultivars, climate, area of cultivation, maturation, postharvest handling, size, and storage condition.

**Table 2. Chemical composition of sweet potato flour**

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (%, db)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Research Result</td>
</tr>
<tr>
<td>Moisture (% wb)</td>
<td>6.83±0.22</td>
</tr>
<tr>
<td>Protein</td>
<td>4.27±0.19</td>
</tr>
<tr>
<td>Fat</td>
<td>3.54±0.18</td>
</tr>
<tr>
<td>Ash</td>
<td>2.32±0.26</td>
</tr>
<tr>
<td>Carbohydrate (by-difference)</td>
<td>83.04±0.50</td>
</tr>
</tbody>
</table>

Source: Susilawati and Medikasari [21]

**Swelling power of modified sweet potato flour**

Swelling power of sweet potato flour after HMT can be seen in Figure 1. Based on statistical analysis, there was a significant interaction (p≤0.05) of temperature and time of HMT in affecting swelling power of the modified sweet potato flour.

![Swelling power of modified sweet potato flour](image)

**Note:** Different superscript notation on each value shows significant difference (p≤0.05)

**Figure 1.** Effect of HMT temperature and time on swelling power of modified sweet potato flour

From Figure 1, sweet-potato flour treated with HMT at 77°C for 3h and 6h exhibited the highest swelling volume of 13.77±0.02 g/g and 13.35±0.03 g/g, respectively, with no significant difference. On the other hand, sweet potato flour treated with HMT at 93°C for 9h gave the lowest swelling volume, which is 8.10±0.17 g/g. In addition, swelling power of the control is 13.16±0.04 g/g, where independent t-test showed that there was a significant difference (p≤0.05) between control and HMT modified flour at 77°C for 3h in terms of swelling power.
According to Santosa et al. [22], amylopectin chain formation occurs during the heating process in HMT, this causes an increase in swelling power. In addition, Santosa et al. [22] reported that an increase in amylopectin chains makes the crystalline structure of starch to be more stable, thus, it can make more hydrogen bonds with water. The swelling power of flour depends on the water holding capacity through hydrogen bonds, as such, HMT can increase the swelling power of flour. However, a longer time and higher temperature modification in the HMT process can lead to a lower swelling power. This happens due to an increase in amylose-amylopectin interactions, stronger intermolecular bonding, and formation of amylose-lipid complex [23] that may create a stronger matrix difficult to swell.

**Solubility of modified sweet potato flour**

Solubility of sweet potato flour after HMT can be seen in Figure 2. Based on statistical analysis, there was a significant interaction (p≤0.05) of temperature and time of HMT in affecting solubility of the modified sweet potato flour. Based on Figure 2, sweet potato flour treated with HMT at 93°C for 9 h gave the highest solubility, which is 50.21±0.18%. In contrast, sweet potato flour treated with HMT at 77°C for 3 h had the lowest solubility, which is 24.09±0.11%. In addition, solubility of the control is 19.54±0.20% where independent t-test shows that there was a significant difference (p≤0.05) between control and HMT modified flour at 77°C for 3 h in terms of solubility.

![Figure 2. Effect of HMT temperature and time on solubility of modified sweet potato flour](image)

Note: Different superscript notation on each value shows significant difference (p≤0.05)

**Lightness of modified sweet potato flour**

Lightness of sweet potato flour after HMT can be seen in Figure 3. Based on statistical analysis, there was a significant interaction (p≤0.05) of temperature and time of HMT in affecting the lightness value of the modified sweet potato flour. From Figure 3, sweet potato flour treated with HMT at 77°C for 3 h had the highest lightness value, which is 72.00±0.05. In contrast, sweet potato flour treated with HMT at 93°C for 9 h had the lowest lightness value, which is 61.13±0.14, although it did not significantly different with sweet potato flour treated with HMT at 85°C for 6 h and 9 h, which had lightness value of 63.25±0.18 and 61.63±0.02, respectively.

Lightness of sweet potato flour without modification obtained from this research is 72.86±0.35 where independent t-test shows that there was a significant difference (p≤0.05) between control and HMT modified flour at 77°C for 3 h in terms of lightness.
Note: Different superscript notation on each value shows significant difference (p≤0.05)

**Figure 3.** Effect of HMT temperature and time on lightness of modified sweet potato flour

From Figure 3, the higher the temperature and the longer the HMT time, the lower the lightness value. The result is similar to the experiment done by Kim et al. (2017) [25], which stated that the darkening effect caused by HMT was more noticeable as the HMT temperature and time are increased. According to Fetriyuna et al. [11], flour that is subjected to heat will undergo color change due to the non-enzymatic browning reaction, which leads to the decrease in lightness value of the modified flour.

**Selected temperature and time of HMT based on swelling power of modified sweet potato flour**

Based on the swelling power properties, sweet potato flour treated with HMT at 77°C for 3 h exhibited the highest swelling power value of 13.77±0.02 g/g. The higher the swelling power is expected to increase the pan bread volume. Therefore, sweet potato flour treated with HMT at 77°C for 3 h was selected to be partially incorporated in the preparation of pan bread.

**Chemical composition of modified sweet potato flour and control**

The chemical composition of the unmodified (control) and selected modified sweet potato flour of the best Heat Moisture Treatment (HMT) temperature and time (at 77°C for 3 h) can be seen in Table 3.

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (% db)</th>
<th>Sweet Potato Flour without Modification (Control)</th>
<th>Sweet Potato Flour HMT 77°C, 3 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%) wb</td>
<td>6.83±0.22b</td>
<td>4.67±0.02a</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>4.27±0.19a</td>
<td>3.94±0.03a</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>4.02±0.30a</td>
<td>3.54±0.18a</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>1.81±0.09a</td>
<td>2.32±0.26a</td>
<td></td>
</tr>
<tr>
<td>Carbohydrate (by difference)</td>
<td>83.04±0.50a</td>
<td>85.57±0.32b</td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>78.69±0.54a</td>
<td>77.16±3.31a</td>
<td></td>
</tr>
<tr>
<td>Amylose</td>
<td>26.51±4.65a</td>
<td>24.91±2.07a</td>
<td></td>
</tr>
<tr>
<td>Amylopectin</td>
<td>73.49±4.65a</td>
<td>75.09±2.07a</td>
<td></td>
</tr>
</tbody>
</table>

Note: Different superscript notation on each value shows significant difference (p≤0.05)

Based in Table 3, starch content of sweet potato flour was decreased after modification with HMT from 78.69±0.54 to 77.16±3.31%. Independent t-test shows that there was no significant difference (p>0.05) between control and HMT modified flour at 77°C for 3 h in terms of starch content. Starch content of sweet potato flour produced was different with research done by Siwi [26], which stated that starch content of sweet potato flour is 49.91%. According to Widyasaputra and Yuwono [27], the different composition obtained
from this research might be due to variation of cultivars, climate, area of cultivation, maturation, size, and/or storage condition. Starch content is decreased due to the degradation of starch, especially in amylose fraction of starch granules. Starch granules are damaged due to the heating process that leads to amylose leaching [28].

It can also be seen that amylose content of sweet potato flour was decreased after HMT from 26.51±4.65 to 24.91±2.07%. Independent t-test shows that there was no significant difference (p>0.05) between control and HMT modified flour at 77°C for 3 h in terms of amylose content. Amylose content of sweet potato flour produced was different with research done by Siwi [26], which states that amylose content of sweet potato flour is 27.73%. The reason for different composition might be the same as for starch content described above. According to Garnida et al. [29], the decrease of amylose content after HMT happens due to the binding of amylose-amylose and amylose-amylopectin during modification, therefore amylose content decreases. Santosa et al. [22] also stated that after HMT, amylose leached out from starch granules, which causes the amylose content to be reduced.

Shown also in Table 3, the amylopectin content of sweet potato flour was increased after HMT from 73.49±4.65 to 75.09±2.07%. Independent t-test shows that there was no significant effect (p>0.05) between control and HMT modified flour at 77°C for 3 h in terms of amylopectin content. Amylopectin content of sweet potato flour produced was different with research done by Siwi [26] stated that amylopectin content of sweet potato flour is 23.17%. The reason for different composition might be the same as for starch content described above. Through HMT process, swelling power is increased because heating process induces the formation of amylopectin chains. The longer the modification time will increase the length of amylopectin chain. Therefore, the increase in chain length will make crystalline structure of flour more stable and uniform, thus creating much more hydrogen bond with water molecules [22].

**Effect of ratio of wheat flour to selected modified sweet potato flour on physical properties of pan bread**

**Weight**

Weight of breads produced can be seen in Figure 4. Based on statistical analysis, it indicates that there was a significant effect (p≤0.05) of different ratio of wheat flour to modified sweet potato flour on the weight of breads produced.

From Figure 4, among treatments, pan bread with the ratio of 90:10 had the highest weight (535.96±0.22 g). On the other hand, bread with ratio of 100:0, which is the control, had the lowest weight (509.87±1.75 g). According to Shittu et al. [30], bread weight is affected by the amount of moisture and carbon dioxide diffused out of the loaf during baking. A reduction in carbon dioxide retention capacity in the dough leads to a decrease in bread weight. The carbon dioxide retention capacity is highly correlated with gluten content.

**Volume**

Volume of pan breads produced can be seen in Figure 5. Based on statistical analysis, it indicates that there was a significant effect
(p≤0.05) of different ratios of wheat flour to modified sweet potato flour on the volume of pan breads produced.

![Graph showing the effect of ratio of wheat flour to modified sweet potato flour on the volume of pan breads produced.](image)

Note: Different superscript notation on each value shows significant difference (p≤0.05)

**Figure 5.** Effect of ratio of wheat flour to modified sweet potato flour on volume of pan breads produced

From Figure 5, the highest volume was (2146.83±0.76 cc) bread with the ratio of 90:5. In contrast, bread with the ratio of 70:30 had the lowest value (949.50±2.78 cc). The increase of volume in pan breads with the ratio of 95:5 and 90:10 was attributed to the increased swelling power of modified sweet potato flour due HMT modification. When starch comes into contact with water, starch granules absorb water and swell. During baking, starch dilutes the gluten that breaks down the gluten structure. Water that is released by the gluten is completely absorbed by starch granules, causing the starch to swell as more and more water enter. Since only limited amount of water is present, the starch is only partially gelatinized. Thus, most of the water remains tightly bound to the swollen starch in the resulting bread [31]. On the other hand, the decrease in volume of pan breads with ratio of 85:15 to 70:30 was due to severe lack of gluten to entrap air during proofing. Thus, there was less incorporation of air bubbles in the dough that causes a volume depressing effect on pan breads [32]. Therefore, with modification through HMT at 77 °C for 3 h, it increased the volume of bread until 10% substitution. Above that, the volume of bread decreased due to severe lack of gluten content in which its function could not be compensated by the modified sweet-potato flour above 10% addition.

**Hardness**

Hardness of breads produced can be seen in Figure 6. Based on statistical analysis, it indicates that there was a significant effect (p≤0.05) of different ratio of wheat flour to modified sweet potato flour on the hardness of breads produced. From Figure 6, pan bread with the ratio of 70:30 had the highest hardness (1556.74±38.16 g). On the other hand, bread with the ratio of 95:5 had the lowest value of hardness (423.92±30.29 g), although it was not significantly different with control (456.95±38.14 g). Wang et al. [33] stated that gliadin and glutenin contained in wheat flour will form gluten when mixed with water. Gluten will create the crumb structure and soften the crumb texture due to its ability to retain gas and moisture. According to Marleen [34], decrease in gluten content in bread dough makes the dough to be more hydrophilic, therefore, there will be stronger interaction between starch granules. Sharma et al. [35] also stated that the increase in firmness is because of the reduced gluten content that also reduced the gas retention during proofing and baking that makes the bread to be less elastic. Thus, substitution of wheat flour with the modified sweet potato flour decreased the gluten content causing the bread hardness to increase.
Note: Different superscript notation on each value shows significant difference (p≤0.05)

**Figure 6.** Effect of ratio of wheat flour to modified sweet potato flour on hardness of breads produced

**Crust lightness**
Crust lightness of the breads produced can be seen in Figure 7. Based on statistical analysis, it indicates that there was a significant effect (p≤0.05) of different ratio of wheat flour to modified sweet potato flour on the crust lightness of breads produced.

From Figure 7, among treatments, bread with the ratio of 70:30 had the highest lightness value, which is 71.22±0.29. In contrast, bread with the ratio of 95:5 had the lowest lightness value (56.29±2.59), although it was not significantly different with control (58.37±0.69) and bread with the ratio of 90:10 (57.10±0.22). During baking, flour type and non-enzymatic browning reaction have an important role in developing crust color. Bread contains reducing sugars and amino groups. When heated, caramelization and Maillard reaction occurs. Maillard reaction is reaction between amino group with carbonyl group of reducing sugar [36]. Therefore, the higher the protein content, then Maillard reaction will be more intensive and reduce the crust lightness.

**Crumb lightness**
Crumb lightness of the breads produced can be seen in Figure 8. Based on statistical analysis, it indicates that there was a significant effect (p≤0.05) of different ratio of wheat flour to modified sweet potato flour on the crumb lightness of breads produced. From Figure 8, pan bread with the ratio of 95:5 had the highest lightness value (82.65±0.32) although it was not significantly different with control (82.36±0.69) and bread with the ratio of 90:10 (81.47±0.32). According to Pusuma et al. [37], crumb lightness is influenced by the lightness of flours used. Wheat flour has lightness value of 74.94-76.38, whereas the lightness of modified sweet potato flour was lower, which was 72.00±0.05. Therefore, as the wheat flour concentration decreased, the crumb lightness also decreased.
Note: Different superscript notation on each value shows significant difference (p \leq 0.05)

**Figure 8. Effect of ratio of wheat flour to modified sweet potato flour on crumb lightness of pan breads produced**

### Effect of ratio of wheat flour and selected modified sweet potato flour on sensory properties of pan bread

#### Scoring values

The result of scoring test can be seen in Table 4. Based on statistical analysis, there was a significant effect (p \leq 0.05) of different ratio of wheat flour to selected modified sweet potato flour on the crust color, crumb color, firmness, aroma, and taste of breads produced.

In terms of crust color, pan bread with the ratio of 80:20 had the highest score (5.01±0.02). The results indicate that bread produced with the ratio of 90:10 had the lightest color. According to Pourafshar et al. [36], both Maillard reaction and caramelization occur during baking. Therefore, less substitution of wheat flour results in higher protein content that made the Maillard reaction happened markedly.

**Table 4. Scoring values of pan breads**

<table>
<thead>
<tr>
<th>Pan Bread (Wheat flour : Selected Modified SPF)</th>
<th>Crust Color</th>
<th>Crumb Color</th>
<th>Firmness</th>
<th>Aroma</th>
<th>Taste</th>
</tr>
</thead>
<tbody>
<tr>
<td>100:0 (Control)</td>
<td>3.96±0.02$^b$</td>
<td>2.40±0.04$^a$</td>
<td>2.94±0.03$^a$</td>
<td>2.02±0.03$^a$</td>
<td>1.71±0.05$^a$</td>
</tr>
<tr>
<td>95:5</td>
<td>4.46±0.02$^a$</td>
<td>2.79±0.02$^b$</td>
<td>2.98±0.04$^b$</td>
<td>2.05±0.04$^a$</td>
<td>1.97±0.01$^b$</td>
</tr>
<tr>
<td>90:10</td>
<td>3.26±0.01$^b$</td>
<td>3.03±0.04$^c$</td>
<td>3.39±0.03$^b$</td>
<td>2.09±0.03$^a$</td>
<td>2.11±0.04$^c$</td>
</tr>
<tr>
<td>85:15</td>
<td>4.39±0.02$^a$</td>
<td>3.27±0.03$^c$</td>
<td>3.75±0.00$^c$</td>
<td>2.36±0.01$^b$</td>
<td>2.33±0.04$^d$</td>
</tr>
<tr>
<td>80:20</td>
<td>5.01±0.02$^a$</td>
<td>3.64±0.03$^a$</td>
<td>3.86±0.04$^d$</td>
<td>2.46±0.08$^b$</td>
<td>2.68±0.04$^a$</td>
</tr>
<tr>
<td>75:25</td>
<td>4.88±0.00$^b$</td>
<td>4.14±0.03$^a$</td>
<td>4.33±0.01$^b$</td>
<td>2.81±0.05$^d$</td>
<td>3.19±0.03$^d$</td>
</tr>
<tr>
<td>70:30</td>
<td>4.23±0.01$^c$</td>
<td>4.53±0.01$^a$</td>
<td>4.66±0.02$^d$</td>
<td>3.36±0.01$^b$</td>
<td>3.56±0.04$^d$</td>
</tr>
</tbody>
</table>

Note: Different superscript notation on each value shows significant difference (p \leq 0.05)

In terms of crumb color, bread with the ratio of 70:30 had the highest score (4.53±0.01). The results indicate that bread produced with the ratio of 70:30 was extremely yellow. According to Choi et al. (2012) [38], crumb color is mainly influenced by the color of flours used. Wheat flour has higher lightness value, therefore, substituting wheat flour with selected modified sweet potato flour decreased the lightness of bread.

In terms of firmness, bread with the ratio of 70:30 had the highest score (4.66±0.02). The results indicate that bread produced with the ratio of 70:30 was extremely firm. Panelists scored lower firmness for ratio 95:5 but it is similar to the firmness score of the control. According to Sharma et al. [35], lower gluten content due to the substitution reduces the gas retention during proofing and baking that makes the bread to be less elastic. Therefore, as the substitution of wheat flour with the selected modified sweet potato flour increased, the firmness increased also due to the lower gluten content, however, the firmness of the control should be taken into consideration.
In terms of aroma, bread with the ratio of 70:30 had the highest score (3.36±0.01). The results indicate that bread produced with the ratio of 70:30 had the oddest aroma. According to Pusuma et al. [37], ingredients used in the making of bread influence the aroma of bread produced. Therefore, as the addition of modified sweet potato flour increased, the aroma of sweet potato also increased markedly, resulting in an odder aroma in bread.

In terms of taste, bread with the ratio of 70:30 had the highest score (3.56±0.04). The results indicate that bread produced with the ratio of 70:30 had the oddest taste. This result is in accordance with research done by Mitiku et al. [39] that more substitution of sweet potato flour into bread increased the odd taste of bread since the taste of a product is highly affected by the ingredients used.

**Hedonic values**

Hedonic test results can be seen in Table 5. Based on statistical analysis, there was significant effect (p≤0.05) of different ratios of wheat flour to selected modified sweet potato flour on crust color, crumb color, firmness, aroma, taste and overall acceptance.

<table>
<thead>
<tr>
<th>Pan Bread (Wheat Flour : Selected Modified SPF)</th>
<th>Crust Color</th>
<th>Crumb Color</th>
<th>Firmness</th>
<th>Aroma</th>
<th>Taste</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>100:0 (Control)</td>
<td>5.33±0.00a</td>
<td>5.93±0.00a</td>
<td>5.69±0.02a</td>
<td>5.64±0.02a</td>
<td>6.00±0.04a</td>
<td>5.86±0.03a</td>
</tr>
<tr>
<td>95:5</td>
<td>4.99±0.03b</td>
<td>5.71±0.04c</td>
<td>5.60±0.04c</td>
<td>5.69±0.01c</td>
<td>5.98±0.01d</td>
<td>5.78±0.04c</td>
</tr>
<tr>
<td>90:10</td>
<td>5.57±0.01a</td>
<td>5.49±0.01c</td>
<td>5.22±0.06d</td>
<td>5.59±0.01d</td>
<td>5.81±0.03a</td>
<td>5.64±0.01a</td>
</tr>
<tr>
<td>85:15</td>
<td>5.24±0.03c</td>
<td>5.49±0.05c</td>
<td>4.91±0.02d</td>
<td>5.45±0.00c</td>
<td>5.60±0.00d</td>
<td>5.52±0.03d</td>
</tr>
<tr>
<td>80:20</td>
<td>4.89±0.02a</td>
<td>5.11±0.05c</td>
<td>4.74±0.05c</td>
<td>5.14±0.05c</td>
<td>5.19±0.01c</td>
<td>5.28±0.04c</td>
</tr>
<tr>
<td>75:25</td>
<td>5.04±0.02a</td>
<td>4.84±0.02a</td>
<td>4.58±0.00b</td>
<td>5.06±0.02b</td>
<td>5.09±0.03b</td>
<td>5.04±0.05b</td>
</tr>
<tr>
<td>70:30</td>
<td>5.04±0.05d</td>
<td>4.78±0.03a</td>
<td>4.27±0.03a</td>
<td>4.93±0.07a</td>
<td>4.84±0.02a</td>
<td>4.90±0.00a</td>
</tr>
</tbody>
</table>

Note: Different superscript notation on each value shows significant difference (p<0.05)

In terms of crust color, bread with the ratio of 90:10 showed the highest acceptance (5.57±0.01). In terms of crumb color, bread with the ratio of 100:0 showed the highest acceptance (5.92±0.00). In terms of firmness, bread with the ratio of 100:0 showed the highest acceptance (5.69±0.02). In terms of aroma, bread with the ratio of 95:5 showed the highest acceptance (5.64±0.02), although it was not significantly different with bread with the ratio of 100:0 (5.64±0.02). In terms of taste, bread with the ratio of 100:0 showed the highest acceptance (5.98±0.00), although it was not significantly different with bread with the ratio of 95:5 (5.98±0.01). In terms of overall acceptance, bread with the ratio of 100:0 showed the highest acceptance with the value of 5.86±0.03. More addition of modified sweet potato flour lowered the overall acceptance of bread. In general, higher overall acceptance is exhibited by pan breads with ratios of 95:5 and 90:10 which also exhibited superior volumes.

**Selected pan breads based on physical and organoleptic properties**

Best formulations of bread were selected based on the volume, hardness measurement and overall hedonic test results. From those results, pan breads with the ratio of 95:5, 90:10 and 85:15 exhibited similar results to the control. Therefore, pan breads with the ratio of 95:5, 90:10 and 85:15 were selected as the best formulated pan breads based on physical and organoleptic properties where then, chemical composition of these selected pan breads was analyzed.

**Chemical composition of selected pan breads**

Chemical composition of pan breads with the ratios of 95:5, 90:10 and 85:15 can be seen in Table 6. Based on statistical analysis, there was a significant effect (p≤0.05) of ratios of wheat flour to selected modified sweet potato flour on moisture, fat, protein, ash, and carbohydrate contents of pan breads made.

Based on the protein content, pan bread with the ratio of wheat flour to selected modified sweet potato flour of 95:5 was chosen as the best formulation since it has the most similar composition to the control, which are 9.82±0.10 and 10.17±0.11%, respectively.
Table 6. Chemical composition of selected pan breads

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount (%, db)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100:0 (Control)</td>
</tr>
<tr>
<td>Moisture (%, wb)</td>
<td>36.21±0.07a</td>
</tr>
<tr>
<td>Protein</td>
<td>10.17±0.11c</td>
</tr>
<tr>
<td>Fat</td>
<td>8.39±0.54a</td>
</tr>
<tr>
<td>Ash</td>
<td>2.02±0.08a</td>
</tr>
<tr>
<td>Carbohydrate (by difference)</td>
<td>43.21±0.60d</td>
</tr>
</tbody>
</table>

Note: Different superscript notation on each value shows significant difference (p≤0.05)

**Pan breads further selected based on chemical composition and volume**

Based on the protein content, pan bread with the ratio of wheat flour to selected modified sweet potato flour of 95:5 was chosen as the best formulation since it had the most similar composition to the control pan bread. Based on the volume, pan breads with the ratio of wheat flour to selected modified sweet potato flour of 95:5 and 90:10 were selected since they exhibited superior volume compared to the control pan bread. Therefore, pan breads with the ratio of 95:5 and 90:10 i.e., partial substitutions by HMT-modified sweet-potato flour of 5 and 10% were selected as the best formulated pan breads in terms of physicochemical and organoleptic properties.

**Conclusion**

Based on research results, heat-moisture treated sweet potato flour with heating temperature and time of 77°C and 3 h exhibited the highest swelling power, which was 13.77±0.02 g/g. Pan breads with the ratio of 95:5, 90:10 and 85:15 gave the similar results to the control bread in terms of hardness and overall hedonic test results. Based on the protein of the selected pan breads, pan bread with the ratio of 95:5 gave the most similar composition to the control breads. Based on the volume, however, pan breads with the ratio of 95:5 and 90:10 were selected since they have higher volume of 2146.83±0.76 cc and 1942.83±5.51 cc, respectively, than the control pan bread (1833±80.36 cc).

Up to now, the usual pan bread made with wheat flour always exhibited superior properties, however, it is found out in this research that pan breads with the ratio of 95:5 and 90:10 exhibited markedly higher volumes as compared to the pan bread prepared with wheat flour without substitution. Therefore, pan breads with the ratio of 95:5 and 90:10 may have a potential to be adopted for commercial production.

**Suggestion**

Further research can be done by combining different methods of starch modifications, such as autoclaving and cooling to see whether different modification methods may give better swelling power and better properties to the pan bread produced.

**Conflicts of interest**

The authors declare that there is no conflict of interest regarding the publication of this paper.

**References**


