Partial Substitution with Heat-Moisture Treated Sweet Potato (*Ipomoea Batatas* L.) Flour to Wheat Flour Affecting Physicochemical and Organoleptic Characteristics of Pan Bread

Wilbur Donald Raymond Pokatong, Febiana Christy

Food Technology Study Program, Faculty of Science and Technology, Universitas Pelita Harapan Jl. MH. Thamrin Boulevard, Tangerang 15811, Banten, Indonesia
wilbur.pokatong@uph.edu

Abstract. Bread products including pan bread are widespread as staple food. Wheat flour is the main ingredient used. However, Indonesia must import wheat flour, and demand increases every year. To reduce wheat flour dependency, partial substitution of wheat flour with a local crop e.g., sweet potato might be done. However, due to poor properties of native sweet potato flour for bread making, a modification was needed. This research objectives were to determine effect of Heat-Moisture Treatment (HMT) temperature and time on physicochemical characteristics of sweet potato flour, select best treatment, and determine effect of substitution ratio on physicochemical and organoleptic characteristics of straight-dough pan bread. Sweet potato flour was HMT-modified (61, 69, 77 °C; 3, 6, 9 hrs). Sweet potato flour modified (77°C; 3 hrs) exhibited highest swelling power (13.23±0.27 g/g) and was selected for pan-bread making. Ratios (wheat flour: modified sweet potato flour) in pan bread formulation were 90:10, 85:15, 80:20, 75:25, 70:30. Pan bread (90:10 ratio) exhibited similar protein content to, and markedly higher volume than control's; whereas 85:15 ratio showed similar protein content and bread volume to control's. Overall acceptance of pan breads (90:10, 85:15) was only slightly less than control's. Thus, pan breads (ratios 90:10, 85:15) were selected as best formulated pan bread with moisture, fat, protein, ash, and carbohydrate content of 37.74±0.16%, 8.83±0.08%, 14.83±0.04%, 1.51±0.07%, 37.09±0.04%, and 38.04±0.23%, 10.96±0.64%, 14.33±0.63%, 1.54±0.07%, 35.13±0.07%, respectively. Taken together, partial substitution (10 and 15%) of HMT-modified sweet potato flour replacing wheat flour exhibited, to some extent, better pan bread characteristics.

Keywords: Heat-moisture-treatment, Pan-bread, Sweet-potato-flour.

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1 Introduction

Bread including pan bread is universally accepted staple food. It is a good source of macronutrients and micronutrients that are essential for human health [1]. Pan bread, also referred to as loaf bread or white bread, is a type of bread without the addition of flavorings nor other ingredients [2]. The main ingredient of a pan bread is wheat flour, which is an imported product where its raw material i.e. the wheat grains is imported with a total of 10.3 million tons in 2020 [3]. The increase of wheat flour imports over the years has made Indonesia become dependent on other countries because it is not accompanied with the utilization of potential local crops [4]. Therefore, one of the alternatives to minimize this problem is by developing flour from potential local crops which are potentially substituting partially wheat flour.

Sweet potato as stated by Ayo-Omogie [5] is one of the most distributed root crops that ranks seventh most important food crop in the World and fourth in tropical countries. It is non-seasonal and has a shorter growth period compared to other crops. In addition, sweet potato is also rich in nutrients. Despite these positive features offered by sweet potato, it has not been utilized optimally in the food industry. The partial substitution of wheat flour with sweet potato flour containing no gluten will reduce the gluten content of pan bread. Therefore, modification of the sweet potato flour by heat-moisture treatment (HMT) is needed to improve the swelling ability of pan bread. By partial substitution of wheat flour with heat-moisture treated sweet potato flour in pan bread, it is expected the flour to have better physicochemical and organoleptic characteristics that may compensate the reduced gluten content and are still acceptable for the prospective consumer.

One of the most important characteristics of pan bread is the volume, as it is the key aspect to consumer preference. Therefore, bread producers are interested in increasing the volume of bread while using the same amount of materials (i.e. the same weight of dough). A previous study by Pokatong and Julista [6] has proven that the partial substitution of wheat flour with heat-moisture treated sweet potato flour can improve the physicochemical and organoleptic characteristics of pan bread, especially volume at the ratio of 90:10. In this research, sweet potato flour was prepared the same as described in a report [6] but was modified i.e., using lower temperature regimes and the same time of HMT. The best treatments were determined and selected to be used in the making of pan bread. The effect of partial substitution with selected modified sweet potato flour on pan bread was also determined.

The objectives of this research were to determine effect of Heat Moisture Treatment (HMT) temperature and time on physicochemical properties of sweet-potato flour and employ this HMT-modified sweet-potato flour as partial substitutes for wheat flour in straight-dough pan bread formulations and determine the pan-bread physicochemical and organoleptic characteristics.

2 Materials and Method

2.1 Materials

Materials used in this research were sweet potatoes (*Ipomoea batatas* L.), dried tapioca balls, and "*Cakra Kembar*" wheat flour, modified sweet potato flour, water, "*Fermipan*" yeast, "*Dolphin*" salt, "*Gulaku*" sugar, "*Baker's Bonus A*" bread improver, and "*NZMP*" skim milk powder for pan bread preparation. Other materials used for analyses and assays were of analytical and/or food grades.

2.2 Preparation of Sweet Potato Flour

Sweet potatoes (~5 kg) were washed and peeled using a peeler. The peeled sweet potatoes were cut into thin slices using a slicer and immersed in 0.3% metabisulfite solution to prevent the sweet potatoes from browning. The sliced sweet potatoes were dried in a cabinet dryer at 50°C for 5 hrs. Then, dried slices of sweet potatoes were ground using a dry blender and sieved with an 80-mesh sieve. Starch content, lightness, swelling power, and solubility of the sweet potato flour were analyzed [7].

2.3 Heat-Moisture Modification of Sweet Potato Flour

In research stage I, sweet potato flour (~100 g each batch) previously prepared was subjected to heat-moisture treatment (HMT) based on the HMT modification procedure developed before [8] with modification. Moisture content of the sweet potato flour was adjusted to approximately 30% with the addition of water. The water-reconstituted sweet potato flour was then cooled down at 5°C for 24 h and then let stand in room temperature. The flour was covered with aluminum foil, and heat-moisture treatment was carried out in an oven for certain temperature regimes (61, 69, 77°C) and time (3, 6, 9 hrs). Then, the modified sweet potato flour was dried at 50°C for 5 h, ground, and sieved using an 80-mesh sieve. Lightness, starch content, swelling power, and solubility of the modified sweet potato flour were analyzed [7].

2.4 Preparation of Pan Bread Using Straight Dough Method

In research stage II, pan bread was prepared using different ratios of wheat flour and selected modified sweet-potato flour. The bread formulation was adopted from [9] with modifications (Table 1). Dry ingredients, including different substitution ratios of wheat flour: selected modified sweet potato flour (100:0, 90:10, 85:15, 80:20, 75:25, and 70:30), were mixed thoroughly. Water was then gradually added into the dry mixture and mixed for 2 min with a slow speed and 2 min with a high speed. Shortening was then added into the mixture. The dough was made into a round shape and covered with damp cloth for 10 min. The dough was then formed into a round shape again and covered with damp cloth for another 15 min. Then, the dough was rolled with a rolling pin and placed into a baking pan. The dough was let for proofing at room temperature and then baked at 190°C for 25 min afterwards. The bread was taken out of the oven and let it cool.

Table 1. Formulations for pan bread preparation.

Ingredients \ Ratio	Amount (%)					
	100:0 (Control)	90:10	85:15	80:20	75:25	70:30
Wheat flour	53.19	47.87	45.21	42.55	39.89	37.23
Modified sweet potato flour	0	5.32	7.98	10.64	13.30	15.96
Bread improver	0.27	0.27	0.27	0.27	0.27	0.27
Skim milk powder	3.19	3.19	3.19	3.19	3.19	3.19
Yeast	1.06	1.06	1.06	1.06	1.06	1.06
Sugar	4.26	4.26	4.26	4.26	4.26	4.26
Salt	0.80	0.80	0.80	0.80	0.80	0.80
Water	31.91	31.91	31.91	31.91	31.91	31.91
Shortening	5.32	5.32	5.32	5.32	5.32	5.32
Total	100	100	100	100	100	100

Source: AACC International [9] with modifications

2.5 Analyses

The analyses done on the modified sweet potato flour were swelling power and solubility [10], lightness [11], starch, amylose, and amylopectin content [12], moisture, protein, fat, ash, and carbohydrate content [12]. Those done on the pan bread were weight and volume [13], lightness [11], scoring and hedonic test [14] and moisture, protein, fat, ash, and carbohydrate contents [12].

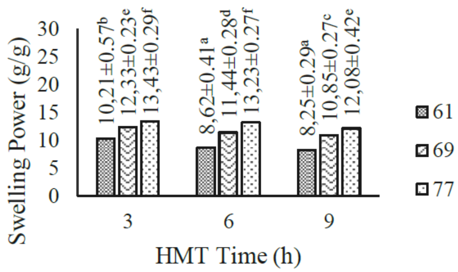
2.6 Statistical Analysis

Statistical analyses of samples were carried out in two replications unless stated otherwise. The analyses were conducted using analysis of variance (ANOVA) using a statistical package for the social sciences (SPSS Inc., Chicago, USA).

3 Results and Discussion

3.1 Effect of HMT Temperature and Time on Physicochemical Characteristics of Sweet Potato Flour

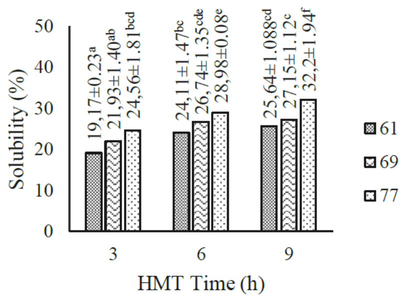
Swelling Power. Swelling power of modified sweet potato flour can be seen in Fig. 1. The results showed that there was a significant interaction ($p \leq 0.05$) of temperature and time of HMT in affecting the swelling power of modified sweet potato flour. As seen in Fig. 1, modification at 77°C for 3 hrs and 77°C for 6 hrs exhibited the highest swelling power which are 13.43±0.29% and 13.23±0.27%, respectively. Meanwhile, sweet potato flour modified at 61°C for 9 hrs and 61°C for 6 hrs gave the lowest swelling power of 8.25±0.29% and 8.62±0.41%, respectively. The result is in accordance with the results in a previous work [15], where HMT done at gelatinization temperature of the produce used would give higher swelling power. According to Li et al. [16], the gelatinization temperature of sweet potato starch is 75°C. As a result, sweet potato flours modified at 77°C gave the highest swelling power. In addition, Sodhi and Singh [17] stated that the chain structure of amylopectin also affects swelling power as it can bind water.



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

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

Solubility. Solubility of modified sweet potato flour can be seen in Fig. 2. The results showed that there was a significant interaction ($p \leq 0.05$) of temperature and time of HMT in affecting the solubility of sweet potato flour. As seen in Fig. 2, sweet potato flour modified at 77°C for 9 hrs gave the highest solubility (32.20±1.94%) while sweet potato flour modified at 61°C for 3 hrs and 69°C for 3 hrs had the lowest solubility of 19.17±0.23% and 21.93±1.40%, respectively. Solubility is positively correlated to temperature. When the temperature increases, solubility will increase as well [18]. Solubility is mainly affected by the amylopectin content, which is correlated positively to HMT time. The increase of long chain amylopectin affects solubility by allowing starch granules to swell and causes amylose to leach out from the starch granule [19].

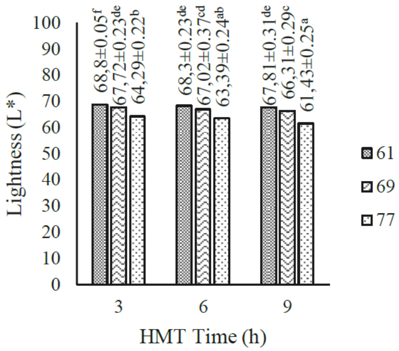


Note: Different superscript notation on each value shows significant difference ($p \leq 0.05$)

Fig. 2. Effect of HMT temperature and time on solubility of modified sweet potato flour.

Lightness. Lightness of modified sweet potato flour can be seen in Fig. 3. The results showed that there was a significant interaction ($p \leq 0.05$) of temperature and time of HMT in affecting the lightness of sweet potato flour. As shown in Fig. 3, sweet potato flour modified at 61°C for 3 hrs had the lightest color at 68.80±0.05, even though it is not significantly different from the sweet potato flours modified at 61°C for 6 hrs, 61°C for 9 hrs, and 69°C for 3 hrs. Sweet potato flour modified at 77°C for 9 hrs and 77°C for 6 hrs had the darkest color at 61.43±0.25 and 63.39±0.24, respectively. As seen on Fig. 3, lightness decreased as the temperature and time increase. The decrease in lightness was due to the Maillard reaction that takes place during the heating process of HMT [20].

For pan-bread preparation, sweet potato flour modified at 77°C for 6 hrs was selected due to the high swelling power, which is 13.23±0.27 g/g. The ability to swell of the selected modified sweet potato flour was expected to increase the volume of pan bread due to its ability to absorb water.



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

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

Chemical Composition of Selected Modified Sweet Potato Flour. The chemical composition of native and selected modified sweet potato flour Heat-Moisture Treated at 77°C for 6 hrs can be seen in Table 2. Moisture content of selected modified sweet potato flour (5.85±0.35%) is lower than the native sweet potato flour (6.83%). The decrease of moisture content is due to the swelling of starch granules during HMT modification that leads to more space for water inside the starch granules to evaporate when heated [21]. A decrease in the fat content of modified sweet potato flour (0.98±0.01%) from the native flour (3.54%) is due to the heating process during HMT that caused carbohydrate to interact with other components such as protein and fat. As stated by Setiyoko et al. [20], they also explain the significant decrease in the protein content of modified sweet potato flour, (in this case from 4.27 to 4.11±0.02%) and the increase in carbohydrate content from 83.04 to 86.53±0.36%. There was an increase in ash content of modified sweet potato flour (2.53±0.04%) from the native flour (2.32%). According to Ayele et al. [22], skin and contaminant residues that were in the flour increase the ash content. Whereas, washing and soaking the sweet potato might strip off some of the vitamins and minerals, therefore reducing the ash content. Starch content of modified sweet potato flour increased from 78.69% to 86.83±1.15%. The increase of starch content was related to moisture. Water facilitates hydrogen bonds within starch granules and form a more compact structure, thus it is more resistant to dissolution and oxidative degradation [23]. Amylose content of modified sweet potato flour (21.76±0.10%) is higher compared to the native flour (20.85%). The increase of amylose content is due to gelatinization, where during gelatinization, molecules of starch realign and some of the amylopectin is hydrolyzed into amylose [24]. Amylopectin content of modified sweet potato flour increased from 57.84% to 65.07±1.24%. According to Correa et al. [25], the difference might be due to the biological characteristics of the sweet potato used, such as the condition and climate of cultivation area, maturity of crop, and storage condition.

Table 2. Chemical composition sweet potato flour and wheat flour.

Component (%)	Treatment		
	Modified Sweet Potato Flour (HMT 77°C, 6 h)	Unmodified Sweet Potato Flour[1)]	Wheat Flour[2)]
Moisture	5.85±0.35	6.83	14.25
Protein	4.11±0.02	4.27	12.50
Fat	0.98±0.01	3.54	0.98
Ash	2.53±0.04	2.32	1.82
Carbohydrate	86.53±0.36	83.04	68.75
Starch	86.83±1.15	78.69	60.50
Amylose	21.76±0.10	20.85	14.8
Amylopectin	65.07±1.24	57.84	45.70

Source: [1)][6] ; [2)][26]

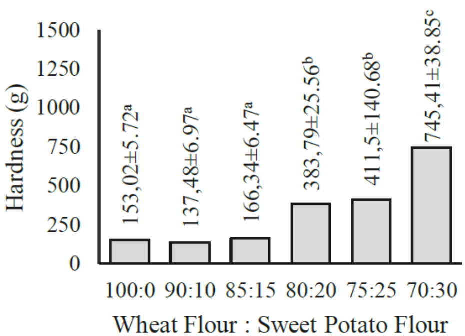
3.2 Effect of Ratios of Wheat Flour to Selected Modified Sweet Potato Flour on Physicochemical and Organoleptic Characteristics of Pan Bread

Weight. Weight of pan bread is shown in Fig. 4. The results showed that ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the weight of pan bread. As seen in Fig. 4, pan bread with ratio of 85:15 gave the highest weight, which is 455.21±0.32 g. Pan bread with ratio of 90:10 and 70:30 gave the lowest weight, which are 439.30±1.02 and 439.43±0.83 g. It was stated in a report [27], high weight loss of bread is due to the ability of dough to absorb water, which eventually evaporates during baking. Other factors such as mixer speed and humidity of the oven also contribute to the weight loss of bread.

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

Fig. 4. Effect of ratios of wheat flour to modified sweet potato flour on weight of pan bread. produced.

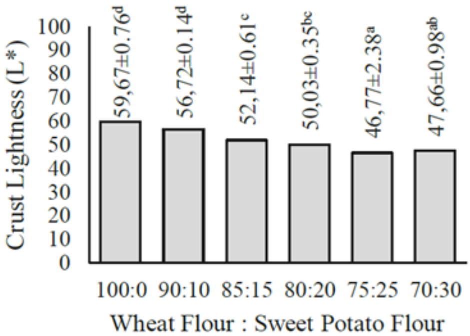
Hardness. Hardness of pan bread is shown in Fig. 5. The results showed that ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the hardness of pan bread. As seen in Fig. 5, pan breads with ratio of 100:0, 90:10, and 85:15 exhibited the lowest hardness, which are respectively 153.02±5.72 g, 137.48±6.97 g, and 166.34±6.47 g. Pan bread with ratio of 70:30 gave the highest hardness, which is 745.41±38.85 g. Partial substitution of 10 and 15% gives the pan bread similar hardness values to the control. The main component responsible for bread texture is gluten. During mixing and hydration of dough, gluten network formed and will retain leavened gas during fermentation and baking. Therefore, control bread up to certain amount of substitution (10%) of flour will result in better crumb, which is porous, airy, and rigid [28]. Pan breads with ratio of 80:20 to 70:30 orderly increased in hardness. The incorporation of HMT flour affected hardness due to the solubility of starch and lack of gluten. Side chains of amylopectin that leach out during heat treatment form a hard gel during cooling, therefore increasing the hardness of the bread [29].



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

Fig. 5. Effect of ratios of wheat flour to modified sweet potato flour on hardness of pan bread produced.

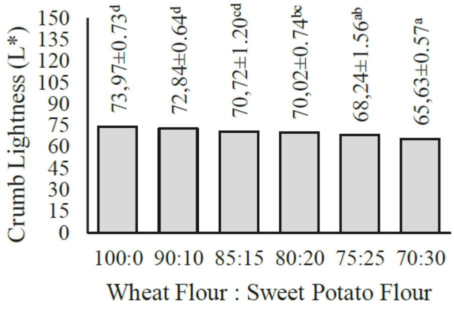
Crust lightness. Crust lightness of pan bread can be seen in Fig. 6. The results showed that ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the crust lightness of pan bread. As seen in Fig. 7, pan bread with ratio of 100:0 and 90:10 gave the highest lightness, which are respectively 59.67±0.76 and 56.72±0.14. Pan breads with ratio of 75:25 and 70:30 gave the lowest lightness, which are respectively 46.77±2.38 and 47.66±0.98. According to Jusoh [30], lightness of bread crust is affected by the protein content, carbohydrate content, and oven conditions. Protein and carbohydrate in bread will undergo caramelization and Maillard reaction, resulting in intense browning of the bread surface.



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

Fig. 6. Effect of ratios of wheat flour to modified sweet potato flour on crust lightness of pan bread produced.

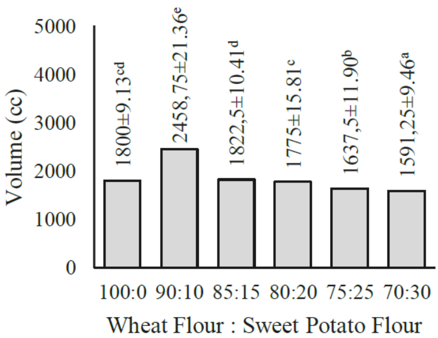
Crumb lightness. Crumb lightness of pan bread can be seen in Fig. 7. The results showed that ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the crumb lightness of pan bread. As seen in Fig. 7, pan bread with ratio of 100:0 and 90:10 gave the highest lightness, which are respectively 73.97±0.73 and 72.84±0.64. Pan breads with ratio of 70:30 and 75:25 gave the lowest lightness, which are respectively 65.63±0.57 and 68.24±1.56. The result is similar to research done by [31], where lightness of crumb will change in accordance to the substitution ratio. As the lightness of modified sweet potato flour is lower than wheat flour, breads with higher substitution ratio will also have lower lightness compared to the control.



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

Fig. 7. Effect of ratios of wheat flour to modified sweet potato flour on crumb lightness of pan bread produced.

Volume. Volume of baked pan bread is shown in Fig. 8. The results showed that ratio of wheat flour to modified sweet potato flour significantly affected (p≤0.05) the volume of baked pan bread. As seen in Fig. 5, pan bread with ratio of 90:10 gave the highest volume, which is 2458.75±21.36 cc and pan bread with ratio of 70:30 gave the lowest volume, which is 1591.25±9.46 cc. Baked pan bread with ratio 90:10 gave higher volume while 85:15 gave similar volume to that of the control. According to Onyango [32], flours with partially gelatinized starch increased water absorption and gas production during fermentation of dough. When starch is heated with water, starch granules absorb water and swell due to the heat. Some of the granules that swell will eventually burst. However, there is only a limited amount of water during bread baking. Therefore, starch granules will not absorb excessive amount of water and are able to maintain the water inside the granules. Starch also interacts with gluten during baking. Gluten structure breaks down and releases water, which is absorbed by the starch granules. The gluten structure will then set and become rigid [33]. The decrease in volume of pan breads with ratio of 75:25 and 70:30 was apparently due to the lack of gluten as a result of reduced amount of wheat flour used.



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

Fig. 8. Effect of ratios of wheat flour to modified sweet potato flour on volume of pan bread produced.

Scoring Values. Based on the results, ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the crust color of pan bread. Pan bread with ratio of 70:30 and 100:0 gave the highest (4.39±0.14) and lowest (2.98±0.10) value, which means bread with ratio of 70:30 had the darkest crust color and 100:0 had the lightest crust color. According to Jusoh et al. [30], higher substitution of flour will result in different rate of caramelization and Maillard reaction. Higher substitution of wheat flour results in the change of carbohydrate and protein content of the bread. Therefore, crust color will change along with increase of substitution ratio.

In terms of crumb color, ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the crumb color of pan bread. Pan bread with ratio of 100:0 and 70:30 gave the highest (4.82±0.12) and lowest (2.84±0.14) value, respectively, which means that the bread with ratio of 100:0 had the least yellow crumb and 70:30 had the most brownish yellow crumb. According to Martins et al. [31], color of crumb will change along with the substitution ratio. Color of the crumb was influenced by the color of the flour, where since the color of modified sweet potato flour is yellow, breads with higher ratio of substitution will also become more brownish yellow.

Ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the firmness of pan bread. Pan bread with ratio of 100:0 and 90:10 exhibited the highest (4.95±0.02) and lowest (2.97±0.12) value, which means that the bread with ratio of 100:0 was the firmest and 90:10 was the softest. Control pan bread was the firmest due to the gluten network, which was responsible for the rigid structure of bread. Pan bread with 90:10 ratio had soft texture due to its ability to swell. The water that was absorbed during mixing and hydration will evaporate during baking [28].

In terms of aroma and taste, ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) the aroma and taste of pan bread. As seen in Table 3, pan bread with ratio of 100:0 and 70:30 exhibited the lowest scores of aroma and taste (1.55±0.10 and 1.63±0.04) and highest scores (2.35±0.02 and 2.70±0.02), respectively, which means that the bread with ratio of 100:0 did not have odd aroma and taste, whereas 70:30 had slightly odd aroma and taste. According to Kunyanga and Imungi [34], aroma and taste of bread will alter along with increased level of substitution.

Table 3. Scoring values of pan bread.

Ratio (Wheat Flour : Modified SPF)	Parameter				
	Crust Color	Crumb Color	Firmness	Aroma	Taste
100:0	2.98±0.10^{a}	4.82±0.12^{b}	4.95±0.02^{c}	1.55±0.10^{a}	1.63±0.04^{a}
90:10	3.60±0.04^{bc}	3.71±0.08^{b}	2.97±0.12^{a}	1.76±0.10^{b}	1.91±0.12^{b}
85:15	3.47±0.10^{b}	3.80±0.16^{b}	3.51±0.08^{b}	2.01±0.02^{c}	1.98±0.02^{b}
80:20	3.20±0.28^{ab}	2.89±0.28^{a}	3.67±0.06^{bc}	2.10±0.10^{c}	2.17±0.04^{c}
75:25	3.97±0.20^{c}	2.94±0.28^{a}	3.85±0.08^{c}	2.13±0.10^{c}	2.60±0.04^{d}
70:30	4.39±0.14^{d}	2.84±0.14^{a}	3.87±0.26^{c}	2.35±0.02^{d}	2.70±0.02^{d}

Note: Different notation indicates a significant difference among samples ($p \leq 0.05$)

Hedonic Values. Ratio of wheat flour to modified sweet potato flour significantly affected ($p \leq 0.05$) all hedonic parameters of pan bread.

Crust color of pan bread with ratio of 100:0 and 70:30 exhibited the highest (5.71±0.08) and lowest (4.75±0.02) acceptance value, respectively. Higher substitution ratio of sweet potato flour decreases the acceptance of crust color of pan bread, as higher substitution ratio results in darker crust color.

Crumb color of pan bread with ratio of 100:0 exhibited the highest acceptance value (5.75±0.06), although it is not significantly different from pan bread with 90:10 ratio (5.51±0.12). Pan bread with ratio of 75:25 had the least acceptance value in terms of crumb color (4.28±0.04), although it is not significantly different from pan bread with ratio of 70:30 (4.38±0.26). Higher substitution ratio of sweet potato flour decreases the acceptance of crumb color of pan bread, as higher substitution ratio results in darker and more brownish yellow crumb color.

Firmness of pan bread with ratio of 90:10 (5.50±0.06) exhibited the highest acceptance value, although it is not significantly different from pan bread with ratios of 100:0 (5.36±0.18) and of 85:15 (5.15±0.02). Pan bread with ratio of 75:25 had the least acceptance value in terms of firmness (4.64±0.18), although it is not significantly different from pan bread with ratio of 70:30 (4.64±0.04). Pan breads with ratio of 100:0, 90:10, and 85:15 were softer compared to pan breads with higher substitution ratio. Higher substitution ratio increased the firmness of bread and resulted in lower acceptance.

In terms of aroma and taste (Table 4), pan bread with ratio of 100:0 and 70:30 gave the highest and lowest value, respectively. As the substitution ratio increase, the odd aroma and taste of bread will also increase. Therefore, pan bread with higher substitution ratio will result in lower acceptance in terms of aroma and taste.

As for the overall acceptance, pan bread with ratio of 100:0 exhibited the highest overall acceptance value (5.98±0.02) followed by that of 90:10 (5.67±0.14). Pan bread with ratio of 70:30 had the least overall acceptance value (4.87±0.02), although it is not significantly different from pan bread with ratio of 75:25 (4.98±0.06). As the substitution ratio increased, the overall acceptance decreased. Based on the result, ratios of 100:0 (control) and 90:10 can be considered as comparable in overall acceptance.

Table 4. Hedonic values of pan bread.

Ratio (Wheat Flour : Modified SPF)	Parameter					
	Crust Color	Crumb Color	Firmness	Aroma	Taste	Overall Acceptance
100:0	5.71 ± 0.08^{b}	5.75 ± 0.06^{d}	5.36 ± 0.18^{c}	5.55 ± 0.06^{c}	5.77 ± 0.04^{d}	5.98 ± 0.02^{e}
90:10	5.47 ± 0.10^{ab}	5.51 ± 0.12^{d}	5.50 ± 0.06^{c}	5.48 ± 0.04^{c}	5.61 ± 0.06^{c}	5.67 ± 0.14^{d}
85:15	5.17 ± 0.08^{ab}	5.34 ± 0.08^{c}	5.15 ± 0.02^{bc}	5.58 ± 0.06^{c}	5.54 ± 0.04^{c}	5.50 ± 0.06^{c}
80:20	5.01 ± 0.06^{ab}	4.74 ± 0.12^{b}	4.93 ± 0.06^{b}	5.52 ± 0.02^{c}	5.38 ± 0.06^{b}	5.32 ± 0.02^{b}
75:25	5.33 ± 0.04^{ab}	4.28 ± 0.04^{a}	4.64 ± 0.18^{a}	5.17 ± 0.04^{b}	5.04 ± 0.02^{a}	4.98 ± 0.06^{a}
70:30	4.75 ± 0.02^{a}	4.38 ± 0.26^{a}	4.64 ± 0.04^{a}	4.96 ± 0.10^{a}	4.96 ± 0.41^{a}	4.87 ± 0.02^{a}

Note: Different notation indicates a significant difference among samples ($p \leq 0.05$)

Selected Pan Breads Based on Physicochemical and Organoleptic Characteristics. Best formulations of pan bread were selected based on its volume, hardness, and overall hedonic test results. Pan breads with ratio of 90:10, 85:15, and 80:20 exhibited similar results in one or more characteristics to those of the control. Therefore, pan breads with the ratio of 90:10, 85:15, and 80:20 were selected and their chemical composition was analyzed.

Chemical Composition of Selected Pan Breads. Chemical composition of selected pan bread can be seen in Table 5. There was no significant effect (p>0.05) of ratios of wheat flour to modified sweet potato flour on the moisture content of pan bread. Although there were not significantly different and if it is seen as absolute numbers, the moisture content (37.74±0.33%) of pan bread partially substituted with modified sweet potato flour was slightly higher as compared to the control (37.50±0.33%). According to Santoso *et al.* [19], HMT treatment of sweet potato flour caused the long chains of amylopectin to form resulting in the increase of hydrogen bonds. Therefore, amylopectin chains bonded with water molecules and pan breads that were made with HMT modified sweet potato flour resulted in higher moisture content.

Table 5. Chemical composition of control and selected pan bread.

Component (%)	Ratio			
	100:0 (Control)	90:10	85:15	80:20
Moisture	37.50±0.33[a]	37.74±0.16[a]	38.04±0.23[a]	37.78±0.71[a]
Protein	15.31±0.09[b]	14.83±0.04[b]	14.33±0.63[b]	13.26±0.40[a]
Fat	8.40±0.17[a]	8.83±0.08[a]	10.96±0.64[b]	14.88±0.19[c]
Ash	1.40±0.01[a]	1.51±0.07[ab]	1.54±0.07[ab]	1.60±0.01[b]
Carbohydrate	37.39±0.41[c]	37.09±0.04[c]	35.13±0.07[b]	32.48±0.89[a]

Note: Different notation indicates a significant difference among samples (p≤0.05)

On the other hand, there was a significant effect (p≤0.05) of ratios of wheat flour to modified sweet potato flour on contents of protein, fat, ash, and carbohydrate of pan bread. As for protein, pan bread with a ratio of 100:0 exhibited the highest content (15.31±0.09%), although it is not significantly different from pan breads with ratios of 90:10 and 85:15 (14.83±0.04% and 14.33±0.63%, respectively). Pan bread with a ratio of 80:20 had the lowest protein content, which is 13.26±0.40%. The decrease of protein content is positively related to the increased amount of sweet potato flour used. Sweet potato flour generally has a low protein content, thus it explains the low protein content in pan bread with higher substitution ratio, where wheat flour also contains higher protein content than sweet potato flour [25].

As for fat, pan bread with a ratio of 80:20 gave the highest fat content (14.88±0.19%), whereas pan bread with a ratio of 100:0 exhibited the lowest fat content (8.40±0.17%) although it is not significantly different with that of 90:10 ratio. Pan bread with higher substitution will result in higher fat content due to the higher fat content in sweet potato flour (1.48±0.8%) compared to wheat flour (0.94±0.01%) [25], [35].

As for ash, pan bread with a ratio of 80:20 exhibited the highest ash content (1.60±0.01%), although it is not significantly different from pan bread with a ratio of 90:10 and 85:15. Control pan bread exhibited the lowest ash content (1.40±0.01%), although it is not significantly different from pan bread with a ratio of 90:10 and 85:15. This result is in accordance to the research done by [25], where the mineral content of sweet potato flour is higher than wheat flour. Therefore, ash content of pan bread is related to the substitution ratio, where as the amount of sweet potato flour increased, the ash content of pan bread also increased.

As for carbohydrate, pan bread with a ratio of 100:0 exhibited the highest carbohydrate content (37.39±0.41%), although it is not significantly different from pan bread with ratio of 90:10 (37.09±0.04%). On the other hand, pan bread with a ratio of 80:20 showed the lowest carbohydrate content of 32.48±0.89%. This result is slightly different from a report by Ijah et al. [36], where bread with higher sweet potato flour content will have higher carbohydrate content due to the higher carbohydrate content in sweet potatoes than in wheat. High amount of carbohydrate in baked products is desirable, since with the presence of water, starch granules can swell and form a gel during heating that is important for the texture and structure of baked products. According to Correa et al. 2018) [25], the differences in the carbohydrate content might be due to the biological characteristics of the sweet potato and the type of sieve used during flour making.

Further Selection of Pan Breads Based on Physicochemical and Sensory Characteristics. Based on the volume of pan bread with ratio of 90:10, 85:15, and 80:20, they were selected due to the similar volume to that of the control. However, based on the chemical composition, only pan bread with ratios of 90:10 and 85:15 was selected due to the similar protein content to the control, which are 14.83±0.04%, 14.33±0.63%, respectively, and 15.31±0.09% (control), there were closest to the control in terms of hedonic overall acceptance. Therefore, pan bread with the ratio of wheat flour to selected modified sweet potato flour of 90:10 and 85:15 was selected since they exhibited markedly better physicochemical (e.g. volume of 90:10 ratio) and comparable organoleptic characteristics to the control.

4 Conclusion

The preparation of Heat-Moisture Treatment (HMT) modified sweet potato flour and pan-bread making were successfully done. The HMT temperature and time affected the swelling power of sweet potato flour where HMT modification of sweet potato flour at 77°C for 6 hrs exhibited the highest swelling power of 13.23±0.27 g/g and was selected for pan-bread making. Pan bread with ratios of 90:10, 85:15, and 80:20 exhibited similar physicochemical and organoleptic characteristics to that of the control. In terms of volume, pan bread with ratio of 90:10 was higher than the control, whereas 85:15 was similar to the control. In terms of the chemical composition, pan bread with ratios of

90:10 and 85:15 also had the most similar protein content to the control. Therefore, pan breads with a ratio of 90:10 and 85:15 were selected since they exhibited markedly better pan bread characteristics (e.g. volume of 90:10 ratio) and comparable hedonic overall acceptance. The moisture, fat, protein, ash, and carbohydrate contents of pan breads with ratios of 90:10 and 85:15 were, respectively, 37.74±0.16%, 8.83±0.08%, 14.83±0.04%, 1.51±0.07%, 37.09±0.04%, and 38.04±0.23%, 10.96±0.64%, 14.33±0.63%, 1.54±0.07%, 35.13±0.07%. Therefore, pan bread with ratios of 90:10 and 85:15 was found to exhibit, to some extent, better characteristics. Taken together, the partial substitution of 10 to 15% in pan-bread formulation might be considered as a potential future alternative in pan-bread production.

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