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Heat-moisture-treated porang (*Amorphophallus muelleri* B.) flour partially substituting wheat flour, affected the physicochemical and sensory characteristics of straight-dough pan bread

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Abstract

Bread, including pan bread, is a staple food widely consumed in many countries across the world. However, in Indonesia, wheat flour used to make pan bread is an imported commodity. Porang (*Amorphophallus muelleri* Blume) may be utilized to partially substitute wheat flour; however, due to the poor properties of porang native flour, a modification is needed to produce flour with better properties. The research objectives were to determine the effect of temperature and time of heat moisture treatment (HMT) modification on physical characteristics of porang flour, to select the best treatment, and to determine the effect of wheat flour on modified porang flour ratios on physicochemical and organoleptic characteristics of pan bread. Porang flour was modified with HMT at 70, 80, 90°C for 6, 8, 10 h. Porang flour (modified 80°C for 10 h) was selected since it exhibited the highest swelling power of 8.05±0.58 g/g. Pan bread was prepared with 95:5, 90:10, 85:15, 80:20, 75:25, and 70:30 substitution ratios. Pan bread with 95:5 ratio exhibited similar volume, hardness, and overall acceptance scores to the control (100:0 ratio) bread i.e., 1002.50±28.17 cc, 547.56±51.21 g, and 5.80±0.14, respectively. Therefore, pan bread can be prepared by partially substituting 5% of wheat flour with HMT modified porang flour.

1. Introduction

It is well known, bread in various forms, including pan bread (locally known as roti tawar) is the main staple food in many countries across the world. Pan bread is widely consumed in Indonesia due to its relatively cheap price and availability (Pusuma *et al.,* 2018). Pan bread is one of the bakery products made without the addition of any filling or flavouring and baked in a loaf pan to give its characteristic format (Ishida and Steel, 2014). Wheat flour, an imported food commodity, is the main ingredient of pan bread, with a total of 10.3 million tons imported in 2020.

Despite being an export commodity, porang (*Amorphophallus muelleri* B.) is not well known by Indonesians and is underutilized. Porang can be utilized as a substitute for wheat flour because of its high amount of starch and other carbohydrates, making it suitable as a raw material for staple foods. However, the substitution of wheat flour with porang flour leads to, due to the lack of gluten, a decrease in pan bread volume, which is one of the most important quality parameters of pan bread (Widodo *et al.,* 2014). Therefore, a modification of this flour is needed to increase its swelling power to produce pan bread with higher loaf volume.

Heat-moisture treatment (HMT) is a physical modification of flour/starch under moderate to low moisture levels and heating at relatively high temperatures for a given period of time. Modification with HMT causes rearrangement of amylose and amylopectin chains in the starch, which in turn modifies the swelling power and amylose leaching (Collar and Armero, 2018). Pokatong and Julista (2022) used HMT-modified sweet potato flour to partially substitute wheat flour in pan bread. The resulting bread exhibited higher volume compared to wheat-flour pan bread at the substitution levels of 5 and 10%.

The objectives of this research were to determine the effect of Heat Moisture Treatment (HMT) temperature and time on physicochemical properties of porang flour, and use this HMT-modified porang flour as a partial substitute for wheat flour in straight-dough pan bread, and determine the pan-bread physicochemical and organoleptic characteristics.

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2. Materials and methods

2.1 Materials

Materials used in this research were porang tubers (*Amorphophallus muelleri* Blume) obtained from Pangandaran, Jawa Barat, Indonesia, tapioca pearls, "Cakra Kembar" wheat flour, HMT modified porang flour, yeast, salt, sugar, bread improver, and "NZMP" skim milk powder, and required reagents/chemicals.

2.2 Porang flour preparation

Porang flour was prepared following the procedures of Haeria *et al.* (2018) and Wahjuningsih and Kunarto (2011) with modifications. Porang (~7 kg) was cleaned, peeled, and cut into 3 mm thickness. The porang slices were soaked in 10% NaCl for 6 h and then rinsed. After that, the slices were dried at 50°C for 48 h. The dried porang slices were subjected to grinding, then sieving with 80-mesh sieves to obtain porang flour.

2.3 Porang flour modification using heat moisture treatment

Porang flour was modified with heat moisture treatment (HMT) according to Indriany *et al*. (2019) and Tanak (2016) with modification. Water was added to porang flour (~50 g) to adjust the moisture content to 30%. The amount of water added was calculated with the following equation:

$$(100\% - MC_1) \times W_1 = (100\% - MC_2) \times W_2$$

MC_1 was the initial moisture content of porang flour, and MC_2 was the moisture content required for heat-moisture treatment (30%). W_1 is the initial weight of the flour and W_2 is the final weight of flour with 30% moisture content. After adjusting the moisture content, the flour was cooled for 12 h at 5°C. Heat moisture treatment (HMT) was done in an oven at different temperatures (70, 80, and 90°C) and times (6, 8, 10 h). After which, the flour was dried at 50°C for 8 h following HMT and then ground, sieved, and packed for further analysis and application. A selected modified porang flour was used to partially substitute wheat flour in pan-bread making.

2.4 Preparation of pan bread substituted with heat moisture treatment modified porang flour

Pan bread was prepared using the selected HMT modified porang flour that partially substituted wheat flour. The straight dough method of the American Association of Cereal Chemists (AACC) Method No. 10-10.03 (AACC International, 2000) was used with modification (Pokatong and Julista 2022). Different ratios of wheat flour to modified porang flour were applied in formulations, which are shown in Table 1.

All dry ingredients (Table 1) were weighed and then mixed for a few minutes. Water was added gradually into the dry mix and mixed for 2 min at slow speed and 2 min at high speed. Shortening was then added, and the dough was mixed again at high speed until homogeneous. The dough was then rounded into a ball shape, covered with a damp cloth, and left for 10 min in a proofing box. The dough was again rounded and then left for another 15 min in the proofing box. After which, the dough was rolled using a rolling pin and then placed into baking pans (250 g each). It was covered with a damp cloth and then proofed for 1 h at 30-35°C and RH of 80-85% in the proofing box. The dough was then baked in the oven for 25 min at 190°C, after which the bread was cooled down and analyzed.

2.5 Chemical composition

Proximate analyses of porang and flour samples were carried out according to the methods described by AOAC INTERNATIONAL (2005), where moisture, protein, fat, and ash were analyzed based on AOAC Official Methods 925.10, 991.20, 920.39, and 923.03, respectively.

Table 1. Formulation of pan bread substituted with modified porang flour.

Ingredients \ Ratio	Amount (g)						
	100:0 (Control)	95:5	90:10	85:15	80:20	75:25	70:30
Wheat flour	53.19	50.53	47.87	45.21	42.55	39.89	37.23
Modified porang flour	0.00	2.66	5.32	7.98	10.64	13.30	15.96
Bread improver	0.27	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	3.19
Yeast	1.06	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	4.26
Salt	0.80	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	31.91
Shortening	5.32	5.32	5.32	5.32	5.32	5.32	5.32
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

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2.6 Total starch, amylose, and amylopectin contents

Starch content determination was performed by "Lab Chem-Mix Pratama, Yogyakarta" using the acid hydrolysis method (AOAC Official Method 8.019). For amylose content, it was also performed by the same laboratory where they used the method by Juliano (1971) developed at IRRI, The Philippines. Approximately 100 mg of a sample was placed into a test tube and added with 1 mL 95% ethanol and 9 mL 1 N NaOH. The solution was then boiled until gel formed, transferred into a 100-mL volumetric flask, and added with 1 mL 1 N acetic acid and 2 mL iodine solution. The solution was diluted to 100 mL and was rested for 20 min. Colour intensity was measured using a spectrophotometer at a wavelength of 625 nm, and then amylose content was calculated. Amylopectin was calculated from the result of total starch and amylose content.

$$\text{Amylopectin} = \text{Total starch} - \text{Amylose}$$

2.7 Calcium oxalate content

Calcium oxalate content in the flour was determined by following Chairiyah *et al*. (2021). A sample of ~2 g was weighed and then dissolved in 10 mL HCl 6N and adjusted to 200 mL with distilled water. It was heated for 1 h at 100°C, cooled, and then diluted to 250 mL with distilled water. The solution was filtered with Whatman no. 1 filter paper and divided into 2 beakers. Then, 4 drops of methyl red were added into the filtrate, followed by addition of NH_4OH until the color turns yellow. It was heated to 90°C, cooled, and filtered. The filtrate was heated to 90°C, and then 10 mL $CaCl_2$ was added. It was cooled and left in the refrigerator overnight. The solution was centrifuged for 10 min at 2500 rpm. After decantation, the precipitate was dissolved using 10 mL 10% H_2SO_4. The separated solution was combined to obtain 20 mL of solution. It was diluted to 300 mL with distilled water. A total of 125 mL solution was taken for titration with standardized $KMnO_4$ until the color turns pink and lasted for 30 s.

$$\text{Calcium oxalate(mg/100g)} = \frac{\text{Volume of } KMnO_4 \times 0.00225 \times 2.4}{\text{Initial weight of flour} \times 5} \times 10^5$$

2.8 Yield determination

Flour yield was determined using this following formula:

$$\text{Yield (\%, db)} = \frac{\text{flour weight (db)}}{\text{raw material weight (db)}} \times 100\ \%$$

2.9 Swelling power and solubility

Swelling power and solubility were determined based on the method of Parwiyanti *et al.* (2016). Approximately 0.1 g of sample was heated in 10 mL distilled water at 85°C water bath for 30 min, where the tube was vortexed at the interval of 0, 5, 15, and 25 min for 10 s each. The tube was then centrifuged at 2000 rpm for 30 min. The supernatant was separated, dried, and weighed for solubility. The precipitate was weighed to obtain swelling power. The swelling power and solubility were calculated using these following formulas:

$$\text{Swelling power} = \frac{\text{weight of sediment (g)}}{\text{weight of sample (g)}}$$

$$\text{Solubility (\%)} = \frac{\text{Weight of dried supernatant (g)}}{\text{Weight of sample (g)}} \times 100$$

2.10 Lightness

Lightness analysis was conducted using Chroma Meter CR-400 where the L* value was the lightness value (Nasir *et al.*, 2020).

2.11 Weight and volume

The weight of the pan bread was measured using a table balance and the volume was measured using the seed displacement method. Seed displacement method utilized tapioca seeds. A container was filled with tapioca seeds until full (V1). After that, pan bread was placed into an empty container and then filled with tapioca seeds until full, it was measured as V2. The pan bread volume was obtained by calculating the difference between V1 and V2 (Rismaya *et al.,* 2018).

2.12 Texture (bread hardness)

Hardness or firmness of bread was examined according to the AACC Method No. 74-10.02 (AACC International, 2000) using a TA-XT texture analyzer. The bread sample was sliced in the middle of the loaf to 20-mm thickness. A 36-mm cylindrical aluminum probe with 25 kg load cell was used. Crumb compression was performed with 2 mm/s test speed, 2 mm/s posttest speed, 5 g trigger force, 10 mm penetration distance, and 5 s between the two-compression cycles.

2.13 Sensory analyses

A 7-point scale hedonic and 6-point scale scoring tests, based on Lawless and Heymann (2010) and Lestari *et al*. (2019), respectively, were used to conduct the analyses with 2 replications and evaluated by 30 untrained panelists (Fellendorf *et al*., 2015).

2.14 Statistical analysis

Statistical analyses of samples were carried out in 2 replications unless stated otherwise. The analyses were conducted using analysis of variance (ANOVA) and t-test when required using a statistical package for the social sciences (SPSS Inc., Chicago, USA).

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3. Results and discussion

3.1 Yield and calcium oxalate of unmodified porang flour

Unmodified porang flour was obtained by processing porang tuber into porang flour. The yield of native (unmodified) porang flour was 8.35±0.32%. The yield of porang-to-porang flour reported by Pratama *et al*. (2020) was 8.67%. The difference in yield might be due to extrinsic and intrinsic factors such as processing steps, degree of maturity, cultivars, place of growth, climate, post-harvest handling, and storage conditions (Pokatong and Julista, 2022).

The calcium oxalate content of native flour was 46.25±0.08 mg/100 g. The value after treatment meets the requirement by SNI 7939:2020 for porang chips (*Amorphophallus muelleri* B.) as raw materials. It falls under the 3rd quality grade, in which the maximum amount of calcium oxalate allowed in 100 g of porang chip is 50 mg. Sliced porang was soaked in 10% NaCl solution for 6 h. The NaCl solution used in native flour production reduced calcium oxalate levels due to the ionization of NaCl in water into Natrium (Na^+) and Chloride (Cl^-) ions. These ions would bind with calcium oxalate forming sodium oxalate and calcium chlorides which are soluble in water (Widari and Rasmito, 2018).

3.2 Effect of heat moisture treatment temperature and time on physical characteristics of porang flour

3.2.1 Swelling power of modified porang flour

The swelling power of modified porang flour can be seen in Table 2. Statistical analysis revealed there was no significant interaction ($p>0.05$) of temperature and time of HMT in affecting the swelling power of modified porang flour. The temperature as an individual factor did not significantly affect ($p>0.05$) either on the swelling power with the values ranging from 6.79±0.27 to 7.14±0.86 g/g. This result was in accordance with a report by Lorlowhakarn and Naivikul (2006). However, the time alone of HMT significantly affected ($p\leq0.05$) the swelling power of modified flour. Porang flour modified at 10 h across temperature regimes exhibited the highest swelling power (7.48±0.57 g/g); whereas porang flour modified at 6 h showed the lowest swelling power (6.46±0.51 g/g). Porang flour modified at 80°C for 10 h had the highest swelling power of 8.05±0.58 g/g, which was higher than that of the native porang flour (control) of 7.48±0.04 g/g.

The swelling power was the highest when modified at 80°C and 90°C which decreased the swelling power. According to Sardiman *et al*. (2021), high temperature accelerates the elongation of the amylopectin chain of the granules during HMT. Long-chained amylopectin can have more hydrogen bonds with water in the double helix, resulting in an increase in the flour swelling power. However, as stated by Vermeylen *et al*. (2006), thermal degradation of amylopectin might cause the reduction of swelling power at a temperature beyond 80°C during HMT, as in the case of a higher temperature of 90°C.

As seen in Table 2b, swelling power was directly proportional to the time of HMT modification. The swelling power of modified flour decreased, and then it increased as the treatment time increased. A similar result was reported by Su *et al*. (2020). High-intensity heat moisture treatment subjected to the flour may have promoted the breakage of amylose-lipid complexes and some hydrogen bonds in the amorphous and crystalline region of the starch (Dudu *et al*., 2019) and loss of relative crystallinity, leading to the increase of the starch's swelling power. Furthermore, structural reconfiguration during HMT may have exposed a greater number of hydroxyl groups in the flour, which facilitated the formation of long-chained amylopectin molecules (Dudu *et al*. 2019).

Table 2. Effect of HMT temperature (a) and HMT time (b) on physical properties of porang flour.

a) HMT temperature

Type of flour	Swelling power (g/g)	Solubility (%)	Lightness (L*)
Native*	7.48±0.04	26.08±0.82	59.85±0.01
HMT 70°C	6.79±0.48^{a}	33.14±3.5^{a}	56.55±0.58^{a}
HMT 80°C	7.14±0.88^{a}	35.32±5.52^{b}	55.47±0.8^{ab}
HMT 90°C	6.84±0.53^{a}	32.5±1.73^{a}	55.03±0.3^{b}

b) HMT time

Type of flour	Swelling power (g/g)	Solubility (%)	Lightness (L*)
HMT 6 hrs	6.46±0.5^{a}	31.08±1.45^{a}	56.05±1.12^{a}
HMT 8 hrs	6.83±0.42^{a}	32.14±1.97^{a}	55.9±1.11^{a}
HMT 10 hrs	7.48±0.57^{b}	37.75±3.71^{b}	55.09±1.37^{a}

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p\leq0.05$). *Native flour parameters were not included in the ANOVA analysis

3.2.2 Solubility of modified porang flour

The solubility of modified porang flour can be seen in Tables 2a and 2b. Statistical analysis revealed there was no significant interaction of temperature and time of HMT in affecting ($p>0.05$) the solubility of modified porang flour. However, the time or temperature of HMT significantly affected ($p\leq0.05$) the solubility of modified flour (Tables 2a and 2b). Porang flour treated at 80°C (35.32±5.52%) and 10 h (37.75±3.71%) exhibited the highest solubility, whereas porang flour treated at 90°C (32.5±1.73%) for 6 h (31.07±1.45%) showed the lowest

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solubility. All solubility of modified porang flour was higher than native porang flour (26.08±0.82%). Deka and Sit (2016) observed a similar result in taro starch. An increase in solubility may be a consequence of the disintegration of starch granules, which may have weakened the amylose-amylopectin bond and increased amylose-water interactions (Dudu *et al*., 2019). In addition, HMT also leads to the formation of water-soluble molecules from small fragments of amylose and amylopectin that may have leached out through opened starch granules of the flour after hydrothermal treatment (Collar and Armero, 2018).

3.2.3 Lightness of modified porang flour

Lightness (L*) values were used to describe the brightness of the flour, where L* value close to 100 indicates whiteness. Tables 2a and 2b show the lightness of modified porang flour. Statistical analysis revealed that there was no significant effect ($p>0.05$) of time (Table 2b), and of the interaction of temperature and time in affecting the lightness of modified flour. However, temperature alone significantly affected ($p\leq0.05$) the lightness of modified porang flour (Table 2a). Porang flour modified at 70°C (56.55±0.5) and 6 h (56.05±1.12) exhibited the highest lightness. In contrast, porang flour modified at 90°C (55.03±0.3) and 10 h (55.09±1.37) showed the lowest lightness. Time of HMT, which did not significantly affect ($p>0.05$) the lightness of porang flour, had values ranging from 55.09±1.37 to 56.05±1.12. The lightness of the HMT modified flour was lower than native porang flour, which is 59.85±0.01. The lightness decreased as the temperature of treatment increased, as reflected by the L* value shown in Tables 2a and 2b. Similarly, Syafutri *et al*. (2015) and Ariyantoro *et al*. (2020) reported a similar decrease in lightness in modified sago and sorghum starch, respectively. HMT modification results in a reduction of lightness. The darkening effect induced by HMT was more pronounced as the treatment temperature increased, which might be mainly due to an elevated non-enzymatic browning reaction, also known as the Maillard reaction, between amino groups from degraded protein and reducing sugar, which produces a dark pigment called melanoidins (Kim *et al*., 2017).

3.2.4 Selected heat moisture treatment conditions based on physical characteristics of modified porang flour

The swelling power and solubility characteristics of HMT flour were used to determine the best treatment combinations of temperature and time of HMT, as higher swelling power is expected to increase the volume of bread when baking. Porang flour modified at 80°C for 10 h was selected to partially substitute wheat flour in pan bread making since it had the highest swelling power of 8.05±0.58 g/g as compared to those of the native porang flour (7.48±0.04 g/g) and other HMT conditions. Starch granules with greater swelling power usually show a harmonious higher amylose leaching or solubility (Kumoro *et al.*, 2012). Starch's capacity to absorb a large amount of water will raise the dough viscosity due to the swollen starch granules. Through this mechanism, water and gas holding capacity are achieved, resulting in higher bread volume (Prameswari *et al.,* 2018).

3.3 Chemical composition of unmodified and selected heat-moisture treatment modified porang flour

Chemical composition of unmodified and selected modified porang flour (80°C for 10 h) can be seen in Table 3. The unmodified flour was used as raw material for modification with HMT at 80°C for 10 h. An independent t-test was conducted to compare the chemical composition of unmodified (native) and modified porang flour and revealed that there were no significant differences between unmodified and selected modified porang flour in terms of protein, starch, amylose, and amylopectin; and significant differences in terms of moisture, fat, ash, and carbohydrate. Previous studies showed that protein and starch (Goel *et al*., 2020), amylose (Bharti *et al*., 2019), and amylopectin (Jiranuntakul *et al*., 2012) all indicated no differences between unmodified and modified flour/starch from several plant sources. On the other hand, moisture (Lio *et al.*, 2015), fat (Goel *et al*., 2020), ash and carbohydrate (Setiyoko *et al.*, 2018) all indicated differences that might be due to various causes described in those previous studies.

3.4 Effect of wheat flour on selected modified porang flour ratios on physicochemical and organoleptic characteristics of pan bread

3.4.1 Weight

The weight of the pan bread produced was shown in Table 4. There was no significant effect ($p>0.05$) of different ratios of wheat flour to modified porang flour on the weight of pan bread, with values ranging from 213.85±2.11 to 217.56±3.18 g. All pan bread produced showed a decrease in weight after baking, and all baked bread loaves partially substituted with modified flour showed a similar weight to the control one. A similar result was reported by Menon *et al*. (2015), who reported a weight increment that was not statistically significant in composite flour bread variants. Higher loaf weight has a positive economic impact on bread sales; hence, weight reduction during baking is undesirable as consumers often get attracted to bread loaves with higher weight,, believing that it has more substance for the same price (Shittu *et al*., 2007). This result indicated that partial

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Table 3. Chemical composition of unmodified and selected HMT-modified porang flour.

Component	Amount (%, db)	
	Unmodified porang flour	HMT Modified porang flour
Moisture	9.97±0.35[a]	6.8±0.28[b]
Protein	11.49±0.04[a]	9.67±0.71[a]
Fat	7.30±0.31[a]	6.13±0.36[b]
Ash	3.41±0.12[a]	5.06±0.33[b]
Carbohydrate	67.87±0.00[a]	72.31±1.08[b]
Starch	73.70±0.09[a]	73.99±2.30[a]
Amylose	7.91±0.02[a]	7.26±0.02[a]
Amylopectin	65.83±0.04[a]	66.75±2.51[a]

Values are presented as mean±SD. Values with different superscripts in the same row are statistically significantly different ($p \leq 0.05$) using T-test comparison.

Table 4. Weight of pan bread substituted with HMT modified porang flour.

Ratio (Wheat flour: Modified porang flour)	Weight (g)
100:0	213.88±5.58
95:5	213.85±2.11
90:10	216.24±0.74
85:15	217.23±1.84
80:20	217.03±2.75
75:25	216.77±3.87
70:30	217.56±3.18

Values are presented as mean±SD.

substitution of wheat flour with modified porang flour has no effect on bread weight; therefore,, it would not reduce the economic value of substituted bread in terms of weight, as consumers would see pan bread partially substituted with modified porang flour as having a similar weight and component profiles to that made from 100% wheat flour.

3.4.2 Hardness

Figure 1 shows the hardness of pan bread. Ratios of wheat flour to modified porang flour significantly ($p \leq 0.05$) affected the hardness of pan bread. Pan bread with 100:0 and 95:5 ratios, which were not significantly different, has the lowest hardness of 444.77±63.78 and 547.56±51.21 g, respectively. On the other hand, pan bread with a 70:30 ratio exhibited the highest hardness of 9354.49±678.00 g.

Bread crumb firmness or hardness is an essential textural attribute as it is associated with consumers' perception of freshness. Starch, protein, and water are the main contributors to the structure of bread. According to Fathi *et al*. (2016), crumb hardness is related to the volume and porosity of the bread, in which increased volume and porosity positively affect the softness of bread. Smaller bread has a more compact and dense texture, resulting in higher hardness (Onyango *et al.,* 2009). The gluten network formed by gliadin and glutenin during mixing and hydration is crucial for obtaining the desired volume and texture in the dough system through its viscoelastic properties (Ngemakwe *et al.,* 2014).

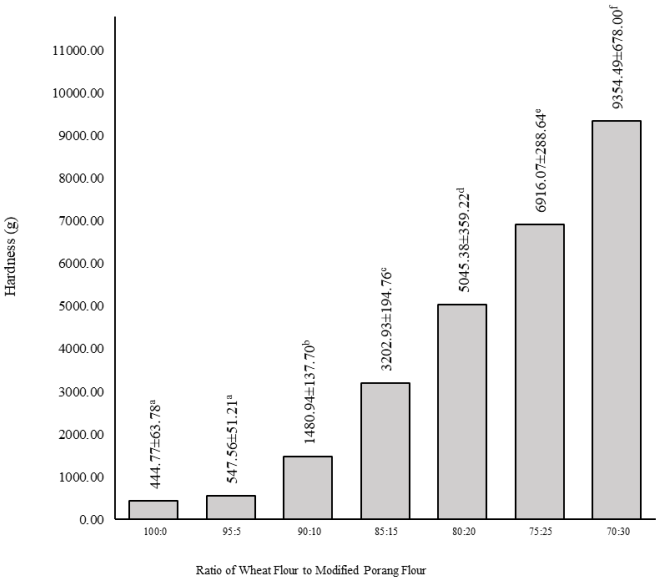


Figure 1. Hardness of pan bread with different ratios of wheat flour and porang flour. Values are presented as mean±SD. Values with different superscripts are statistically significantly different ($p \leq 0.05$).

The hardness value (Figure 1) showed that as the ratio of modified porang flour increased, the hardness of bread also increased, which is in accordance with Akram *et al.* (2017). Increasing the substitution ratio increases pan bread's hardness due to a reduced amount of gluten. Non-wheat flours are characterized by their lack of gluten; therefore, the resulting dough does not have cohesive and elastic properties (Deora *et al*., 2014). The absence of viscoelasticity in the dough will result in less gas retention and lead to a lower volume of the bread and increased hardness. Previous research by Miyazaki and Morita (2005) suggested that HMT modified flour decreases the elasticity of the dough because the modified starch does not bind readily to gluten to form elastic dough during breadmaking; therefore, the dough did not have the strength needed to retain gas produced, which results in bread with low volume.

3.4.3 Crust lightness

The crust lightness of pan bread was shown in Figure 2. There was a significant effect ($p \leq 0.05$) of different ratios of wheat flour to modified porang flour on the crust lightness of the pan bread. Pan bread (Figure 2) with the ratios of 80:20, 75:25, and 70:30 had the highest lightness value, which were 54.17±2.46, 56.40±0.83 and 55.03±2.57, respectively. In contrast, pan bread with a ratio of 100:0 had the lowest lightness value of

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48.59±3.32, and it is not significantly (p>0.05) different from those with ratios of 95:5 (48.89±0.83), 90:10 (50.19±1.42) and 85:15 (51.56±0.83).

Increasing partial substitution of wheat flour with modified porang flour tended to yield a crust with higher lightness (Figure 2). According to Sharma *et al.* (2016), the color of the crust is partly determined by the extent of the Maillard reaction during baking. Bread that contains less protein usually has a crust characterized by higher lightness because there are not enough amino acids available for the Maillard reaction. Baked goods based on starch usually showed a lighter crust since Maillard reactions were reduced (Smidova and Rysova, 2022).

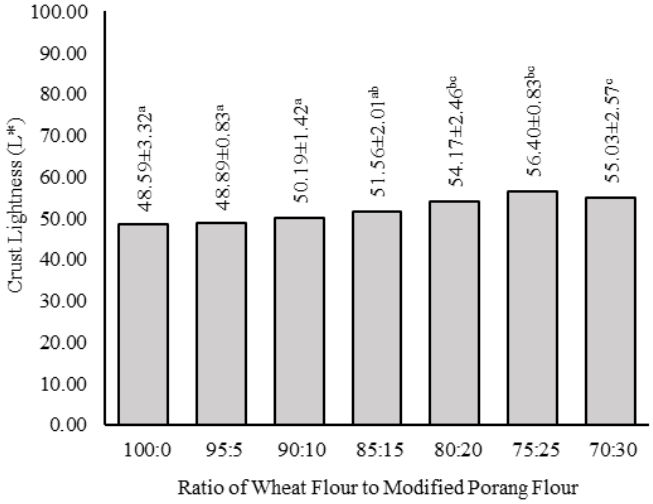


Figure 2. Crust lightness of pan bread with different ratios of wheat flour to porang flour. Values are presented as mean±SD. Values with different superscripts are statistically significantly different (p≤0.05).

3.4.4 Crumb lightness

Crumb lightness was shown in Figure 3. Ratios of wheat flour to modified porang flour significantly affected (p≤0.05) crumb lightness of pan bread. As shown, a decline in lightness was observed with an increasing substitution ratio. Pan bread with a ratio of 100:0 gave the highest lightness, which is 70.40±4.50. In contrast, pan bread with a 70:30 ratio gave the lowest lightness of 58.70±5.08.

Previous studies by Duda *et al.* (2019) observed similar results where the lightness of crumb changes in accordance with the substitution ratio of gluten-free flour. According to Zhou and Hui (2014), the flour used in making bread plays an essential role in the perceived color of the crumb. The lightness of modified porang flour chosen to make the pan bread is 54.55±0.77, while wheat flour's lightness is 74.94-76.38 (Pokatong and Julista, 2022). Furthermore, HMT modification decreases the lightness of porang flour from 59.85±0.01. Therefore, as the wheat flour concentration decreases, the crumb lightness also decreases (Figure 3).

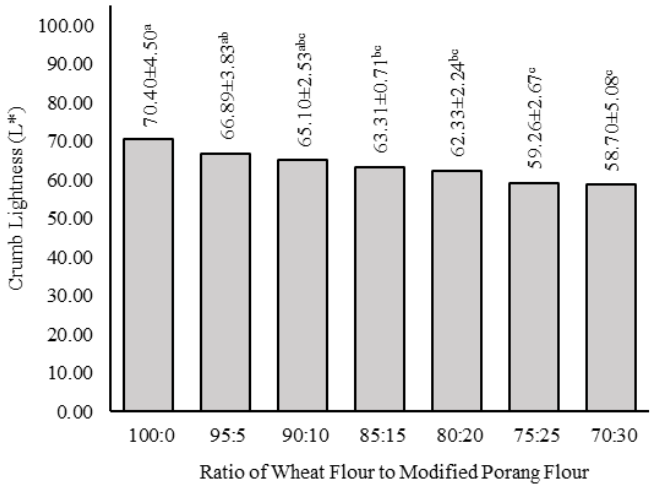


Figure 3. Crumb lightness of pan bread with different ratios of wheat flour and porang flour. Values are presented as mean±SD. Values with different superscripts are statistically significantly different (p≤0.05).

3.4.5 Volume

The volume of pan bread produced can be seen in Figure 4. Ratios of wheat flour to modified porang flour significantly affected (p≤0.05) the volume of pan bread. All pan bread produced had the same dough initial weight of 250 g. Among treatments, pan bread with ratios of 100:0, i.e, the control (1011.67±41.10cc) and 95:5 (1002.50±28.17cc), was not significantly different and exhibited the highest volume. On the other hand, bread with a ratio of 70:30 showed the lowest volume of 331.67±19.09cc.

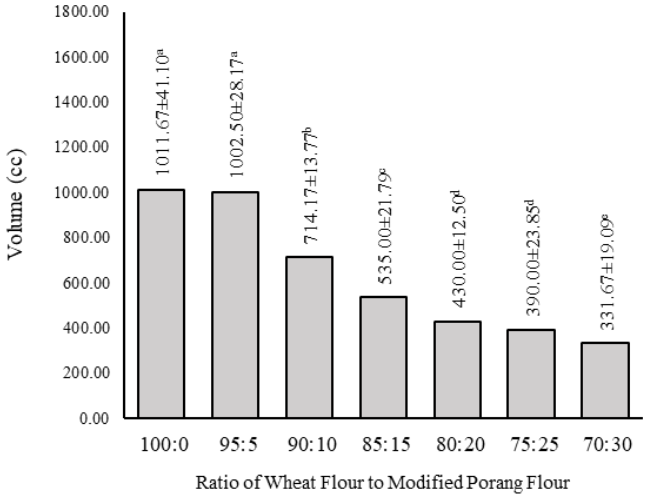


Figure 4. Volume of pan bread with different ratios of wheat flour to porang flour. Values are presented as mean±SD. Values with different superscripts are statistically significantly different (p≤0.05).

As mentioned above, pan bread with the ratio of 95:5 exhibited comparable volume to the control despite having a lower amount of gluten (Figure 5). This proved that HMT modified porang flour used up to a certain

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amount would maintain (not decrease) the volume i.e., the same as that of the control. However, when the substitution was 10% or above, the incorporation of modified porang flour to partially substitute wheat flour significantly reduced the volume. The decline in volume might be caused by the progressively reduced amount of gluten in the formulation, which is actually responsible for trapping gas produced by yeast fermentation.

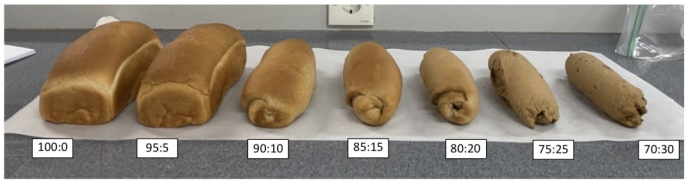


Figure 5. Pan bread of control (100:0) and partially substituted with modified porang flour with substitution ratios shown in the picture.

The gluten network in bread provides the bread volume as it holds gases during proofing and final baking (Aljahani, 2022), and starch controls the dough viscosity during mixing and fermentation, especially in the absence of gluten (Waziiroh *et al*., 2021). During baking, gluten protein denatures and loses its water-holding capacity; while starch absorbs the available water in the dough, swells, and is gelatinized where most of the water in the resulting bread remains tightly bound to the swollen starch; hence, maintaining the volume and softness of bread (Cauvain, 2015). As shown in Figure 5, increased substitutions exhibited a markedly negative impact on bread appearance and size (i.e. volume).

In economic perspectives, high-quality bread is generally associated with high loaf volume and soft crumb (Lapcikova *et al*., 2019). Therefore, bread volume is an important quality parameter for bakers (Elechi *et al*., 2020). A bread volume increase after adding substitutes is a desirable economic value to the baking industry. Customers usually get attracted to bread loaves with higher volume, perceiving that it is worth buying for the same weight and price.

3.4.6 Scoring values

Scoring values of certain parameters of pan bread partially substituted with modified porang flour are shown in Table 5a. There was a significant effect ($p \leq 0.05$) of different ratios of wheat flour to selected modified porang flour on all parameters, i.e., crust color, crumb color, firmness, aroma, and taste of breads produced.

In terms of crust color, pan bread with ratios of 85:15 (3.63±0.05), 75:25 (3.73±0.05), and 70:30 (4.03±0.09) have the highest score, indicating that the crust color is slightly light brown. In contrast, pan bread with 95:5 (3.03±0.14), 100:0 (3.11±0.33), and 80:20 (3.37±0.00) ratios had the lowest score, indicating the

Table 5. Effect of ratio of wheat flour to selected modified porang flour on scoring values (a) and hedonic values (b) of pan bread.

a) Scoring values

Ratio (Wheat flour: Modified porang flour)	Parameter				
	Crust color	Crumb color	Firmness	Aroma	Taste
100:0	3.11±0.33^{a}	4.23±0.52^{a}	2.22±0.12^{a}	1.62±0.21^{a}	1.50±0.14^{a}
95:5	3.03±0.14^{a}	3.65±0.40^{ab}	2.37±0.05^{a}	1.65±0.17^{a}	1.60±0.19^{a}
90:10	3.47±0.38^{ab}	3.17±0.05^{bc}	3.13±0.14^{b}	2.20±0.09^{ab}	2.07±0.00^{a}
85:15	3.63±0.05^{bc}	2.58±0.02^{cd}	3.90±0.42^{c}	2.72±0.26^{bc}	2.73±0.28^{b}
80:20	3.37±0.00^{ab}	2.42±0.17^{d}	4.33±0.05^{c}	2.82±0.26^{cd}	2.95±0.02^{bc}
75:25	3.73±0.05^{bc}	2.35±0.21^{d}	5.00±0.24^{d}	3.07±0.42^{cd}	3.25±0.45^{bc}
70:30	4.03±0.09^{c}	2.00±0.09^{d}	5.02±0.26^{d}	3.38±0.12^{d}	3.52±0.21^{c}

b) Hedonic values

Ratio (Wheat flour: Modified porang flour)	Parameter					
	Crust color	Crumb color	Firmness	Aroma	Taste	Overall
100:0	6.00±0.14^{a}	6.13±0.14^{a}	5.67±0.09^{a}	5.65±0.40^{a}	5.87±0.24^{a}	6.03±0.09^{a}
95:5	5.58±0.45^{a}	5.60±0.00^{b}	5.40±0.12^{ab}	5.42±0.31^{ab}	5.70±0.09^{a}	5.80±0.14^{a}
90:10	5.02±0.02^{b}	4.80±0.05^{c}	4.98±0.02^{b}	4.97±0.00^{abc}	5.25±0.12^{ab}	5.30±0.19^{b}
85:15	4.48±0.02^{c}	4.18±0.35^{d}	4.13±0.12^{c}	4.57±0.71^{abc}	4.65±0.35^{bc}	4.77±0.24^{c}
80:20	3.75±0.12^{d}	3.57±0.24^{e}	3.45±0.35^{d}	4.28±0.64^{bc}	4.32±0.31^{cd}	4.20±0.19^{d}
75:25	3.77±0.05^{d}	3.37±0.09^{ef}	2.93±0.05^{d}	3.97±0.52^{c}	3.78±0.35^{d}	3.73±0.19^{de}
70:30	3.30±0.00^{e}	3.12±0.07^{f}	2.92±0.40^{d}	3.78±0.54^{c}	3.72±0.40^{d}	3.80±0.14^{e}

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p \leq 0.05$).

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color of slightly light brown. Brown crust color formation was caused by caramelization and the Maillard reaction during baking. Amino acids and sugars present in the dough affect the browning reaction (Taghdir *et al*., 2017). Partial substitution of wheat flour with modified porang flour changes the dough's amino acid and sugar content, hence changing the crust color of the bread produced accordingly.

In terms of crumb color, pan bread with 100:0 (4.23±0.52) and 95:5 (3.65±0.40) substitution ratios has the highest score, indicating the crumb color of slightly yellow. In contrast, pan bread with ratios of 85:15 (2.58±0.02), 80:20 (2.42±0.17), 75:25 (2.35±0.21), and 70:30 (2.00±0.09) has the lowest score, suggesting the color is not yellow. The score of crumb color decreases as the substitution ratio increases because the color of the crumb becomes darker and browner. This result is in accordance with Trejo-Gonzales *et al.* (2014), in which the color of crumbs changed with an increasing substitution ratio.

In terms of firmness, pan bread with 100:0 and 95:5 substitution ratios exhibited the lowest score of 2.22±0.12 and 2.37±0.05, respectively, indicating the bread was soft. On the other hand, pan bread with the higher score and, therefore, the bread with the most hardness was bread made with 75:25 and 70:30 substitution ratios with a value of 5.00±0.24 and 5.02±0.26, respectively. Trejo-Gonzales *et al.* (2014) observed a similar result in which the firmness value has an increasing trend with the level of substitution in the bread. According to Rodriguez-Sandoval *et al.* (2017), the crumb firmness increased by increasing gluten-free flour substitution because it decreases the gas retention capacity, dough stability, and protein network stability.

In terms of aroma and taste, pan bread with a 100:0 substitution ratio (control) exhibited the lowest aroma and taste scores of 1.62±0.21 and 1.50±0.14; however, it was not significantly different from those of pan bread with 95:5 and 90:10 ratios, indicating that the bread had no odd aroma or taste. In contrast, pan bread with 80:20, 75:25, and 70:30 ratios exhibited the highest scores of 2.82±0.26, 3.07±0.42, and 3.38±0.12 for aroma and the highest scores of 2.95±0.02, 3.25±0.45, and 3.52±0.21 for taste, respectively. This indicates that a bigger substitution ratio has a more-odd aroma and taste compared to a smaller substitution ratio. According to Choi and Peterson (2010), taste and aroma are influenced by the choice of ingredients, enzymatic reactions occurring during dough fermentation, and thermal reactions during baking. Ingredients used in breadmaking, mainly wheat flour, have distinct characteristics. Wheat flour will undergo several changes during the breadmaking process, which produce the characteristic aroma and taste of bread.

3.4.7 Hedonic values

Hedonic values of certain parameters of pan bread partially substituted with modified porang flour are shown in Table 5b. There was a significant effect ($p \leq 0.05$) of different ratios of wheat flour to selected modified porang flour on all parameters, i.e., crust color, crumb color, firmness, aroma, taste, and overall acceptance of pan breads produced.

Crust color of pan bread with 100:0 and 95:5 ratios is not significantly different and has the highest values of 6.00±0.14 and 5.58±0.45, respectively. On the other hand, crust color of pan bread with a 70:30 ratio had the lowest value of 3.30±0.00, indicating panelists slightly dislike the crust color. The acceptance of crust color decreases as the substitution ratio increases. Pan bread with a 95:5 and 100:0 ratio was perceived to have a slightly light brown color. Scoring and hedonic test indicate that panellist like pan bread with a slightly light brown crust color.

Crumb color of pan bread with a 100:0 substitution ratio acceptance had the highest value of 6.13±0.14; whereas those of pan bread with 75:25 (3.37±0.09) and 70:30 (3.12±0.07) ratios had the lowest score, indicating that the color of the crumb was slightly disliked. A higher substitution ratio decreases crumb color acceptance because the color of the crumb becomes darker and browner. Pan bread with 100:0 and 95:5 ratios had slightly yellow crumb color, which are preferred by the panelists.

Firmness of pan bread with 100:0 and 95:5 ratios was the same, having the highest values of 5.67±0.09 and 5.40±0.12, respectively. In contrast, the ratio of 70:30 pan bread had the lowest acceptance of firmness of 2.92±0.40, although it was not significantly different from the 80:20 (3.45±0.35) and 75:25 (3.97±0.52) ratios. This indicates that the panelists slightly disliked the firmness of the pan bread of high substitution ratios, where the acceptance of firmness decreases as the substitution ratio increases. By considering the values of the scoring test conducted by the panelists, pan bread with 100:0 and 95:5 ratios had a soft crumb. This is in agreement with the result of the hedonic test, indicating that panellists like pan bread that is soft.

Aroma of pan bread with the substitution ratio of 100:0 had the highest value of 5.65±0.40. However, it was not significantly different with 95:5 (5.42±0.31), 90:10 (4.97±0.00), and 85:15 (4.57±0.71) substitution ratios. In contrast, pan bread with a substitution ratio of

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70:30 had the lowest score of 3.78±0.54. As the substitution ratio increases, the acceptance of aroma gradually decreases. Panelists perceived the aroma of pan bread with 100:0. 95:5, and 90:10 as not odd, indicating that panelists preferred pan breads without odd aroma.

Taste of pan bread with 100:0 (5.87±0.24), 95:5 (5.70±0.09), and 90:10 (5.25±0.12) ratios was the most liked by the panelists, as those ratios had the biggest scores. On the other hand, 80:20 (4.32±0.31), 75:25 (3.78±0.35), and 70:30 (3.72±0.40) had the lowest score among all the treatments. The panelists preferred pan bread with a lower substitution ratio because a higher substitution of wheat flour with modified porang flour produced bread with a slightly odd taste, as shown by the scoring taste values.

The overall acceptance of the pan bread with 100:0 and 95:5 substitution ratios was the same and had the highest values of 6.03±0.09 and 5.80±0.14, respectively. Pan bread with 75:25 (3.73±0.19) and 70:30 (3.80±0.14) ratios had the lowest score, indicating that the panelists did not like pan bread with higher substitution ratios. The overall acceptance scores gradually decreased as the substitution ratio increased. Pan bread with 100:0 and 95:5 ratios was characterised with slightly light brown crust color, yellow crumb color, soft texture, without odd taste and aroma, and with the highest values for overall acceptance.

3.5 Selected pan bread based on physicochemical and organoleptic characteristics

The best pan bread formulation was selected based on the volume, hardness, and overall hedonic test results. Pan bread with a 95:5 ratio exhibited comparable results, i.e., was not significantly different from that of 100:0 ratio (control) in terms of volume, hardness, and overall hedonic scores. Therefore, pan bread with 95:5 ratio was selected as the best formulation based on those characteristics.

3.5.1 Chemical composition of selected pan bread

Pan bread selected based on the physicochemical and organoleptic characteristics was analysed for its chemical composition. The chemical composition of the control and selected pan bread (95:5 ratio) can be seen in Table 6. An independent t-test was conducted to compare the means of 100:0 and 95:5 chemical compositions and revealed that there were no significant differences between pan breads of the control (100:0) and the selected one (95:5) in terms of moisture, protein, fat, and carbohydrate. This indicates that the addition of modified porang flour at 5% was not enough to change the composition profiles of these substances in both pan breads.

On the other hand, the ash content of pan bread with a 95:5 ratio was significantly different. Pan bread with a 100:0 ratio has a lower ash content of 2.02±0.13%. Incorporating modified porang flour to partially substitute wheat flour in pan bread with a 95:5 ratio increases the ash content to 2.40±0.05%. The result is in accordance with Lamiaa and Hala (2017), who reported an increase in ash content in pan bread partially substituted with sweet potato flour. The increase in ash content was attributed to the ash content of modified porang flour, which is 5.06±0.33%; whereas, the ash content of wheat flour was 0.64% i.e., lower than modified porang flour. Therefore, incorporating modified porang flour will increase the ash content (Novika *et al.*, 2013).

Table 6. Chemical composition of control and substituted pan bread.

Component	Pan bread with ratio	
	100:0 (Control)	90:5
Moisture	26.97±0.95[a]	28.01±1.73[a]
Protein	13.06±0.29[a]	13.03±0.58[a]
Fat	9.19±0.60[a]	8.93±0.88[a]
Ash	2.02±0.13[a]	2.40±0.05[b]
Carbohydrate	48.76±1.09[a]	47.63±2.75[a]

Values are presented as mean±SD. Values with different superscripts in the same column are statistically significantly different ($p \leq 0.05$).

4. Conclusion

The modification of porang flour with heat moisture treatment (HMT) has been successfully done. Modification with HMT increased the swelling power and solubility but decreased the lightness of porang flour. Porang flour modified at 80°C for 10 h was selected as the best treatment as it exhibited the highest swelling power of 8.05±0.58 g/g. The selected HMT modification was applied to porang flour, which was used to partially substitute wheat flour in pan bread preparation using the straight dough method. The weight of pan bread was not significantly affected by different ratios of wheat flour to modified porang flour. Pan bread hardness, volume, crust lightness, crumb lightness, and organoleptic characteristics were significantly affected by different ratios of wheat flour to modified porang flour. Pan bread with 95:5 ratio substitution exhibited a similar result to that with 100:0 (control) ratio in terms of volume, hardness, and overall acceptance score. As the volume of pan bread is the most important parameter to determine successful substitution, pan bread with a 95:5 ratio was selected as the best formulation and its chemical composition was analyzed. Chemical

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compositions (moisture, fat, protein, and carbohydrate) of pan bread partially substituted wheat flour with 5% HMT modified porang flour in the preparation of pan bread using the straight dough method were similar to those of the control pan bread. Taken together, pan bread can be made by partially substituting 5% of wheat flour with HMT modified porang flour that would still exhibit comparable volume and other characteristics to regular (control) pan bread.

Conflict of interest

The authors declare no conflict of interest.

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