Partial Substitution of Wheat Flour with Heat-Moisture Treated Porang Flour Affected Physicochemical and Organoleptic Characteristics of Pan Bread Prepared with Sponge-Dough Method

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Abstract. Pan bread using wheat flour is one of primary staple foods; however, Indonesia imports wheat in large amount. Local crops utilized as flour stocks e.g. porang (*Amorphophallus muelleri* B.) may reduce imported wheat dependency. Nevertheless, due to porang-flour low solubility and swelling power, modification is needed. The research objectives were to determine effect of heat-moisture treatment (HMT) temperature and time on swelling power, solubility, and lightness of porang flour, to select best treatment, and to determine effect of substitution ratios on physicochemical and organoleptic characteristics of sponge-dough pan bread. Porang flour modification was done with HMT (70, 80, 90ºC; 6, 8, 10 h) resulted in increased solubility and swelling power in some cases. Modification at 80ºC; 10 hrs exhibited highest swelling power (8.05±0.58g/g); thus, was selected for pan-bread making. Pan bread was prepared with ratios: 95:5, 90:10, 85:15, 80:20, 75:25, 70:30 (wheat flour:modified porang flour). Pan bread (90:10 ratio) exhibited similar volume (887.5±40.59cc) and hardness (824.364±52.30g) to control, and comparable hedonic overall acceptance. Pan bread with partial substitution of wheat flour with modified porang flour, exhibited increased in some proximate compositions but decreased in protein and carbohydrate. Pan bread with 10% substitution could be a future alternative in pan-bread production.

1 Introduction

Bread products are one of the highly consumed primary foods. It is often made from cereals such as wheat and rye along with water, yeast, and salt [1]. However, based on an article by Anonim 2023 [2], wheat is still greatly imported from other countries. Therefore, a solution to decrease the dependency on wheat flour is to develop and substitute wheat flour using an alternative source of flour.

Porang (*Amorphophallus muelleri* B.) is a local Indonesian crop that optimally grows in tropical countries with an altitude 100-600 m above sea level and can usually be found in forest areas [3]. The presence of glucomannan may also replace some of gluten's role by bonding with water and forming thin film layer that retains gas in bread production

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[4]. However partially substituting wheat flour with porang flour creates the lack of gluten and a decrease in bread volume and structure, therefore modification of flour is needed [5].

Heat moisture treatment (HMT) is a method of flour alteration that exerts heat to the flour until certain characteristics is reached [6] which in this case HMT is expected to improve the swelling power of porang flour. The increase in swelling power resulted in high volume of bread due to the water availability in the flour matrix that increases the crosslinking of starch and gluten, and creation of stronger network of gluten resulting in better retention of gas during baking [7]. The research objectives were to determine effect of HMT temperature and time on porang flour characteristics i.e. swelling power, solubility, and lightness, to select best treatment, and to determine substitution ratio effect on physicochemical and organoleptic characteristics of sponge-dough pan bread.

2 Research methodology

2.1 Materials

Materials used were porang (*Amorphophallus muelleri* B.) tubers purchased from Pangandaran, wheat flour (*Cakra Kembar*), modified porang flour, yeast (*Fermipan*), bread improver (Baker A Bonus), salt (*Dolphin*), sugar (*Gulaku*), and skim milk powder (NZMP), tapioca pearls, "Amidis" distilled water, and required reagents/chemicals.

Equipment used in this research were, among others, "Cimarec" heater, centrifuge "Hettich Zentrifugen EBA 200," centrifuge tube, analytical balances "Sartorius" and "Ohaus Adventurer," "Heidolph" rotary evaporator, "Konica Minolta" CR-400 chromameter, Texture analyzer TA-XT plus, and all other necessary laboratory equipment for processing and/or analysis.

2.2 Procedures

2.2.1 Preliminary research

The preparation of porang flour was adapted from Wahjuningsih and Kunarto [8], Ulfa and Nafi'Ah [9], Haeria et al. [10]. The porang tubers (~ 7 kg) were firstly peeled, washed and cut to slices with 3 mm thickness. Then it was immersed in 10% NaCl solution for 6 hrs and then rinsed with distilled water (Amidis). The sliced porang tubers were dried at the cabinet dryer at 50ºC until the slices were dry. The slices were then reduced in size using herb grinder and sifted with an 80-mesh sieve.

2.2.2 Main research stage I

Porang flour obtained from the preliminary research stage was modified using HMT. The modification of the porang flour (~ 50 g) was adapted from Indriani et al. [11] and Tanak [12].

The moisture content of the porang flour was adjusted to approximately 30% with the addition of water. The water amount which needs to be mixed was estimated using the formula below:

$$(100\% - CM_1) \times M_1 = (100\% - CM_2) \times M_2 \quad (1)$$

CM_1 was the original moisture content of the porang flour and CM_2 was the wanted moisture content of the flour which was 30%. M_1 was the original weight of the flour and M_2 was the weight after water has been added. The porang flour was then stored at ~5°C for 12 hrs, afterward the heat-moisture treatment was done in a closed condition wrapped with aluminium foil was done in an oven. The treated porang flour was the dried at 50°C for 8 hrs, reduced in size, and sifted with an 80-mesh sifter. The obtained modified flour was then analyzed for its lightness, swelling power and solubility. Selection of the best treatment was done based on the highest swelling power and then the selected modified porang flour obtained from the treatment is analyzed for its proximate, starch, amylose and amylopectin content.

2.2.3 Main research stage II

Pan bread was prepared with the method of sponge dough where firstly the sponges were prepared by mixing 50% of wheat flour, selected modified porang flour and water according to the ratios with all of the yeast for 60 min to form the sponge. Then the sponge was moved to a covered bowl and was fermented at the proofing box for 60 min, with punching at 20 and 40 min. Then, the rest of the ingredients were added and mixed thoroughly with the sponge for 20 min until homogenous dough is formed. The dough obtained was proofed for 20 min. Then dough was panned at the baking pan and is final proofed for 20 min [13]. Lastly, the dough was baked at the oven at temperature 190ºC for 25 min [14].

Pan bread was made by employing different ratios of wheat flour to chosen treated porang flour. Ingredients and formulation of pan bread are as shown in Table 1.

2.2.4 Procedures of analyses

Yield determination

Yield of porang flour obtained from porang tubers was calculated using AOAC method [15] with modification, which is done firstly by weighing the porang tubers after peeling. Then the porang tubers was then processed into flour. The yield was determined based on the formula below.

$$\text{Yield (\%)} = \frac{\text{final product weight}}{\text{raw material weight}} \times 100\ \% \tag{2}$$

Swelling power

Approximately 0.1 g flour was mixed with 10 mL distilled water and heated in a water bath for 30 min at 85°C and was then vortexed for 10 s on 5-, 15-, and 25-min intervals. The sample was then spun form 30 min at 2000 rpm, after which the precipitate was then weighed [16].

$$\text{Swelling power} = \frac{\text{weight of sediment (g)}}{\text{weight of sample (g)}} \tag{3}$$

Table 1. Ingredients and formulations of pan bread

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	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

Source: AACC International [17] with modification in Pokatong and Julista [18]

Solubility

Approximately 0.1 g flour was mixed with 10 mL distilled water and heated in a water bath for 30 min at 60°Cnd stirred constantly. The flour was then spun (10 min at 1600 rpm). The supernatant was dried and weighed [16].

$$\text{Solubility (\%)} = \frac{\text{Weight of dried supernatant (g)}}{\text{Weight of sample (g)}} \times 100 \quad (4)$$

Lightness

Lightness was measured using a chromameter. From the measurement, the L* value indicated the sample lightness [19].

Calcium oxalate content

The content of calcium oxalate in the flour was measured by following Chairiyah et al. [20]. Two grams of porang flour were added in Erlenmeyer 250 mL then was added with 190 mL of distilled water afterward it was mixed with 10 mL of 6M HCl. The suspension was then heated at 100°C for 1 hr and then cooled. Then water was added until mixture reaches 250 mL and then was filtered. The filtrate obtained was then separated into 2, 125 mL each. Filtrate was then added to beaker glass and was added with 4 drops of methyl red indicator. Then it was added with NH_4OH until mixture turns from bright red to pale yellow. Mixture was then heated until it reaches 90°C and was added with 10mL $CaCl_2$ 5% and was mixed. The filtrate obtained was cooled and was left in the refrigerator overnight. The solution was spun at 2500 rpm for 10 min. The supernatant was poured out and 20 mL of 10% H_2SO_4 was added to the precipitate. The mixture was then diluted with distilled water to 300 mL. 125 mL of the solution was heated and then titrated with standardized $KMnO_4$ solution until pink color emerged and lasted for 30 s. The calcium oxalate was then calculated.

$$\text{Calcium oxalate (mg/100g)} = \frac{titration\ volume\ (mL)\ x\ Vme\ x\ DF}{sample\ weight\ (g)\ x\ 5} \times 10^5 \quad (5)$$

Total starch

By using the acid hydrolysis method, total starch content was analyzed. Approximately 0.5 g sample was rinsed with distilled water up to where the filtrate reached 250 mL, then filtered with filter paper. The residue was washed with 200 mL water then 20 mL HCl 25% was added into the Erlenmeyer flask and boiled for 2.5 hrs. The solution was cooled and neutralized with 1 N NaOH then diluted to 250 mL. Filter paper was used to filter the solution [15].

$$\text{Total starch} = \frac{\text{X x DF x 100 x 0.9}}{\text{weight of sample}} \tag{6}$$

Amylose

Approximately 100 mg of sample was placed in a test tube and mixed with 1 mL of 95% ethanol and 9 mL of 1 N NaOH. The test tube was heated until gel formed and was placed into 100 mL volumetric flask and added with 1 mL 1 N acetic acid and 2 mL iodine solution. The solution was diluted in a 100-mL volumetric flask and rested (20 min). Colour intensity was determined using a spectrophotometer (625 nm wavelength), afterward amylose was determined [15].

Amylopectin

Amylopectin was determined based on the percentage difference between total starch and of amylose [15].

$$\text{Amylopectin (\%)} = \text{total starch (\%)} - \text{amylose (\%)} \tag{7}$$

Weight and volume

The weight of pan bread was determined employing a weighing apparatus and volume was measured using a technique of displacement of seeds. The method was carried out by placing tapioca pearls (seeds) in a container (V1). Pan bread was then placed in that container which was empty and covered with the pearls (V2). The difference between V1 and V2 was the volume of the pan bread [21].

Texture

Texture analyser TA-XT plus was used to examine the texture of the bread. The parameter assessed was crumb hardness. The bread sample was taken from the middle of the loaf with a size of 25 x 25 mm and 20 mm thickness. The texture was assessed by equipping a 25 kg load cell with a 36 mm cylindrical aluminium probe. A two-cycle test is done using P/36R probe (test speed 2.0 mm/s, trigger force 50 g, post-test speed 10.00 mm/s, distance 10 mm, and time between compression cycle 5 s). The peak force of compression would be reported as hardness.

Sensory analysis

A 7-point scale hedonic test and a 6-point scale scoring test, both based on Pimentel et al. [22] were used to conduct the analyses with 2 replications and evaluated by 30 untrained panelists [23].

Statistical analyses

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

3 Results and discussion

3.1 Taxonomical authentication of porang tubers

Plant taxonomy authentication of the porang utilized in the research was carried out at *Badan Riset dan Inovasi Nasional (BRIN) Republik Indonesia* for validation. Based on the result, species of the porang used in this research was indeed confirmed to be *Amorphophallus muelleri* Blume or porang, from the genus of *Amorphophallus* and the family of *Araceae*.

3.2 Yield and calcium oxalate of unmodified *porang* flour

The process of obtaining unmodified porang flour was done by turning porang tubers into porang flour. The yield of porang flour obtained from the porang tubers was 9.22±0.36% which is more than the yield as reported before [24] with the value of 8.67%. The yield difference might be because of extrinsic and intrinsic factors such as processing steps, place of growth, climate, post-harvest handling, storage conditions, degree of maturity, and cultivars [18].

The calcium oxalate content of the unmodified porang flour used in this research is 46.25±0.08 mg/100g which is in accordance with SNI 7939:2020 that set a maximum calcium oxalate content of 50 mg/100g as a requirement if porang to be used as a safe food ingredient for consumption. The consumption limit for calcium oxalate ranges from 0,6-1,25 g/day if consumed for 6 weeks in a row.

3.3 Swelling power of modified *porang* flour

The swelling power of modified porang flour is shown in Table 2. Temperature and time of HMT showed no significant interaction ($p>0.05$) in influencing swelling power of porang flour. However, there was a significant effect ($p\leq0.05$) of individual treatment of time (Table 2) on the swelling power of modified porang flour. It can be seen that porang flour modified at 10 hrs (7.61±0.69 g/g) gave the highest swelling power while porang flour modified at 6 hrs (6.46±0.51 g/g) resulted in the lowest swelling power. Besides that, modification of porang flour at 80°C for 10 h (8.05±0.58 g/g) gave higher swelling power when compared to the unmodified porang flour which has swelling power of 7.48±0.04 g/g.

The swelling power of modified porang flour showed highest value during HMT treatment of 10 hours. This is in accordance with a previous report [25] which stated that duration of HMT results in the disruption of starch crystalline structure, causing water to be absorbed easily. The absorption of water causes starch granules to swell and coincide with one another, increasing the value of swelling power. In addition, the chain structure of amylopectin also affects swelling power where hydrogen bonds in amylopectin chains is also capable of binding water, thus higher amylopectin content leads to a better absorption of water during heating.

Table 2. Effect of HMT time on swelling power of porang flour

Time (hrs)	Swelling Power (g/g)
6	6.46±0.51[a]
8	6.83±0.42[a]
10	7.48±0.57[b]

Note: Superscript notation i.e. different indicates significant difference ($p \leq 0.05$)

3.4 Solubility of modified porang flour

The solubility of porang flour is shown in Table 3. Temperature and time of HMT showed no significant interaction ($p>0.05$) in influencing the swelling power of porang flour. However, there was a significant effect ($p \leq 0.05$) of individual treatment of temperature (Table 3a) and time (Table 3b) on the solubility of porang flour. Results showed that porang flour modified at 80°C (35.32±5.52%) and 10 hrs (37.75±3.71%) exhibited the highest solubility, whereas porang flour modified at 90°C (32.50±1.73%) and 6 hrs (31.179±1.42%) resulted in the lowest solubility value. Results also revealed that all HMT modifications of porang flour exhibited higher solubility as compared to the unmodified porang flour which has solubility of 26.08±0.82%.

Solubility positively related to the duration of the HMT. Meanwhile, the solubility of modified porang flour peaked at the temperature of 80°C and went down at 90°C. This is in accordance with a report before [25] where duration and heating temperature of HMT results in degradation of starches which reduces and shortens chains of starch structure, causing water to be absorbed easily. However, higher heating temperatures can cause decreased solubility due to the damage done to the granules while also inducing faster amylopectin chain elongation [26].

Table 3a. Effect of HMT temperature on solubility of porang flour

Temperature (°C)	Solubility (%)
70°C	33.14±3.50[a]
80°C	35.32±5.52[b]
90°C	32.50±1.73[a]

Table 3b. Effect of HMT time on solubility of porang flour

Time (hrs)	Solubility (%)
6	31.179±1.42[a]
8	32.05±2.03[a]
10	37.75±3.71[b]

Note: Superscript notation i.e. different indicates significant difference ($p \leq 0.05$)

Higher temperature of HMT can also lead to reduced number of hydroxyl groups in starch molecules that interact with water molecules, thus lowering the starch granules' ability to absorb water which is found in the modification of sorghum flour with HMT. Flour with low water holding ability is shown to be more problematic to discharge starch components, particularly amylose, into the dispersing medium i.e. water, causing increased insolubility [27].

3.5 Lightness of modified porang flour

The lightness of porang flour in shown in Table 4. Temperature and time of HMT showed no significant interaction ($p>0.05$) in influencing the swelling power of porang flour. However, there was a significant effect ($p\leq0.05$) of individual treatment of temperature only in affecting the lightness of modified porang flour. Porang flour modified at 70°C (56.55±0.5) and 6 hrs (56.05±1.12) exhibited the highest lightness while porang flour modified at 90°C (55.03±0.3) and 10 hrs (55.03±0.3) resulted in the lowest lightness. All modified flour also exhibited lower lightness value as compared to the unmodified porang flour which has the value of 59.85±0.01.

Table 4. Effect of HMT temperature on lightness of porang flour

Temperature (°C)	Lightness (L*)
70°C	56.55±0.58^{a}
80°C	55.47±0.8^{ab}
90°C	55.03±0.3^{b}

Note: Superscript notation i.e. different indicates significant difference ($p\leq0.05$)

As seen, the lightness of modified porang flour decreases with the increase of HMT temperature. This result is in accordance with a previous report [27] which stated that the blackening effect induced by HMT was significantly more as treatments of temperature and time elevated because of Maillard reaction taking place during the heating process of HMT with the reaction of amino acids from degraded proteins with reducing sugars.

3.6 Selected modified porang flour based on swelling power

Porang flour treated at 80°C for 10 hrs was chosen to be utilized in further main research (2nd Stage) because of its high swelling power (8.05±0.58 g/g). Higher swelling power indicates the ability to hydrate and absorb water, thus the selected porang flour was expected to have a positive impact on increasing the volume of pan bread [28]). The result is supported from the solubility of modified porang flour showing the highest value at treatment 80°C for 10 hrs, where higher solubility indicates higher water uptake and higher swelling power [29].

3.7 Chemical composition of unmodified and selected porang flour

The chemical composition of unmodified and chosen treated porang flour at 80°C for 10 hrs is displayed in Table 5. Statistical analysis of the chemical composition of unmodified and chosen treated porang flour was done using independent t-Test.

From Table 5, significant differences ($p\leq0.05$) between the two flours is shown in terms of moisture, fat, ash and carbohydrate content; whereas, no significant differences ($p>0.05$) in contents (protein, starch, amylose, amylopectin). Different results in chemical composition might be due to the effect of HMT modification applied to the porang flour [30].

Table 5. Chemical composition of unmodified and modified porang flour

Composition	Amount (%, dry basis)

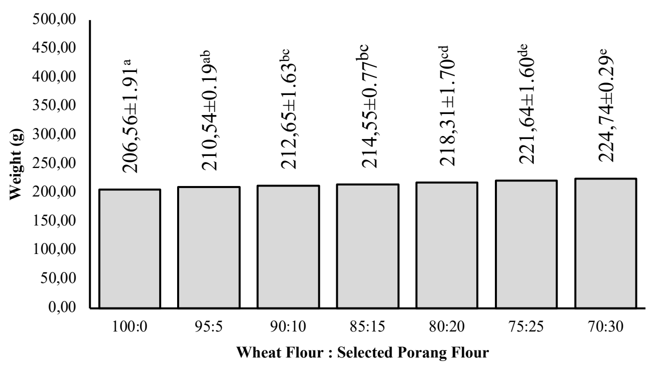
	Unmodified Porang Flour	HMT Modified Porang Flour
Moisture	9.97±0.35[a]	6.8±0.28[b]
Protein	11.49±0.04[a]	9.67±0.71[a]
Fat	7.30±0.31[a]	6.13±0.36[b]
Ash	3.41±0.12[a]	5.06±0.33[b]
Carbohydrate	67.87±0.00[a]	72.31±1.08[b]
Starch	73.70±0.09[a]	73.99±2.30[a]
Amylose	7.91±0.02[a]	7.26±0.02[a]
Amylopectin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

Note: Superscript notations i.e. different on each row indicate significant difference (p≤0.05)

3.8 Effect of wheat flour:chosen modified porang flour ratios on physicochemical characteristics of sponge-dough pan bread

3.8.1 Weight

Pan bread weight can be seen in Figure 1. Statistical analysis revealed that the ratio of wheat flour to modified porang flour showed a significant effect (p≤0.05) on the weight of pan bread. As shown in Figure 1, pan bread (70:30 ratio) exhibited the greatest weight of 224.74±0.65 g and ratio 100:0 the lowest weight of 206.56±3.95 g.



Note: Superscript notation i.e. different indicates significant difference (p≤0.05)
Fig. 1. Effect of wheat flour to porang flour ratios on pan bread weight

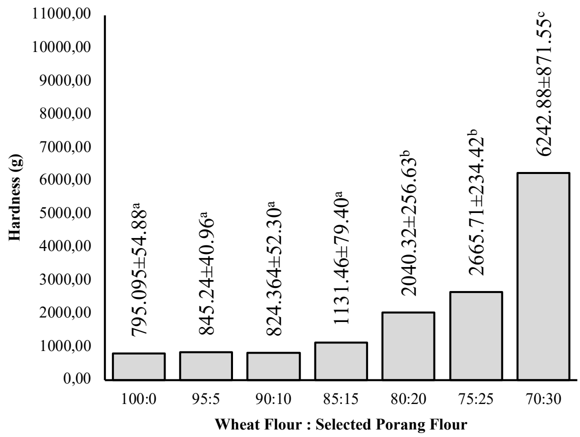
The increase in bread weight might be due to the increase of moisture retention and decrease air entrapment causing bread loaf made from partially substituted modified porang flour to become heavier than the bread loaf made from only wheat flour [31].

3.8.2 Hardness

The hardness of pan bread is displayed in Figure 2. The ratio of wheat flour to modified porang flour showed a significant effect (p≤0.05) on the hardness of pan bread. As shown on Figure 2, pan bread (70:30 ratio) exhibited the greatest hardness of 6242.88± 871.55 g and ratio 100:0 the lowest hardness of 795.10± 54.88 g. Furthermore, the ratio of modified porang flour up to 15% substitution still exhibited no significant difference to the control.

The hardness level of pan bread with 5 and 10% substitution showed similar results to the control and increased orderly with the percent substitution of modified porang flour. Bread hardness is an important parameter in determining bread quality. The hardness level of bread is closely related to the consumer's perception of bread freshness, where softer bread indicates higher bread quality [32].

In the case of bread texture, starch and gluten are responsible in determining the hardness of bread. Gluten network is mainly responsible for the viscoelastic characteristics of dough. The more network of gluten which forms during mixing and hydration of dough the more gas cells to expand and retain gas in the dough, creating an airy, porous and rigid crumb [33]. Meanwhile the lack of gluten in bread results in bread with poorer, harder texture of bread [34].



Note: Superscript notation i.e. different indicates significant difference ($p \leq 0.05$)
Fig. 2. Effect of wheat flour to porang flour ratios on pan bread hardness

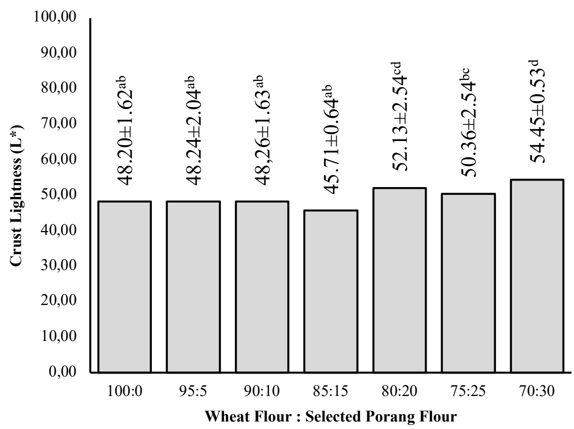
The result is similar to previous research [35] which showed that bread substituted using HMT modified flour showed an increase in hardness. It is found that the substitution of HMT flour influenced the solubility of starch and decreased the gluten content, which in turn increases the hardness of bread.

3.8.3 Crust lightness

The pan-bread crust lightness is shown in Figure 3. Statistical analysis revealed that the ratio of wheat flour to modified porang flour exhibited a significant effect ($p \leq 0.05$) on pan bread crust lightness. As shown in Figure 3, that pan bread with 70:30 ratio exhibited the highest crust lightness of 54.45±0.53 L* and ratio 85:15 the lowest crust lightness of 45.71±0.644 L*.

Bread formulation substituted with modified porang flour of 5, 10, and 15% showed similar results to the control. In contrast, bread formulation with 20, 25, and 30% substitutions showed increasing bread crust lightness.

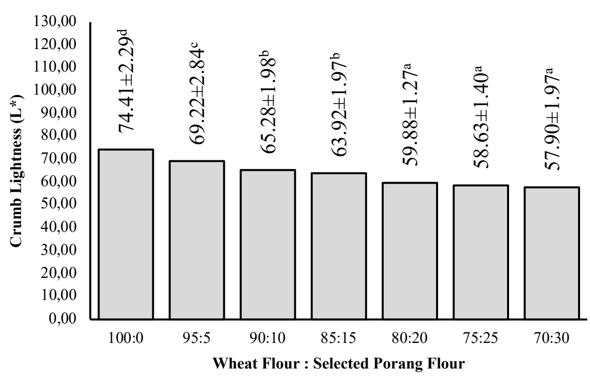
The lightness of crust depends mainly on the temperature and time of baking and the chemical composition of the bread especially protein and reducing sugar content contributing to the browning reaction (Maillard reaction) and the high-temperature caramelization of sugars. Generally, the higher the protein content of bread, the darker the color of the crust would be. The result shows that higher substitution level of modified porang flour yielded in higher crust lightness. This is due to decreased level of protein present causing less Maillard reaction happening on the bread crust [36].



Note: Superscript notation i.e. different indicates significant difference ($p \leq 0.05$)
Fig 3. Effect of wheat flour to porang flour ratios on pan bread crust lightness

3.8.4 Crumb lightness

The crumb lightness of pan bread is displayed in Figure 4. Statistical analysis revealed that wheat flour to modified porang flour ratios showed a significant effect ($p \leq 0.05$) on pan bread crumb lightness. As shown in Figure 4, pan bread with 100:0 ratio exhibited the highest crumb lightness of 74.41±2.29 L* and ratio 70:30 the lowest crumb lightness of 57.90±1.97 L*.



Note: Superscript notation i.e. different indicates significant difference ($p \leq 0.05$)

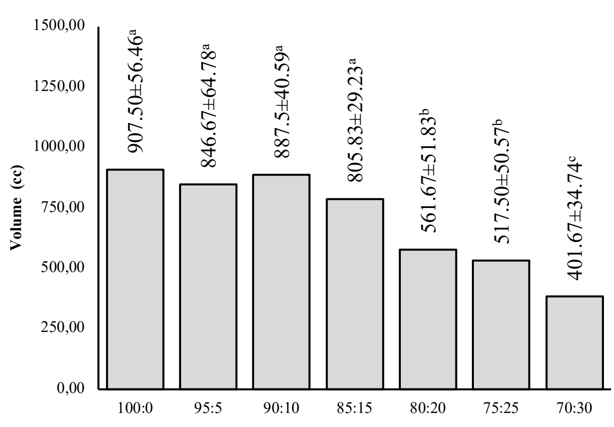
Fig. 4. Effect of wheat flour to porang flour ratios on pan bread crumb lightness

The result shows that the crumb lightness decreases with the increasing amount of modified porang flour substitution. This is similar to previous research [37] which reported the crumb color became increasingly darker as the substitution of chickpea flour increased. In addition, the decrease in lightness is markedly significant when the chickpea flour is thermally treated.

3.8.5 Volume

The volume of pan bread is shown on Figure 5. Based on the statistical analysis, the ratio of wheat flour to modified porang flour showed a significant effect ($p \leq 0.05$) on volume of pan bread. As shown in Figure 5, pan bread (100:0 ratio) exhibited the greatest volume of 907.5±56.46 cc. However, those with ratios 95:5. 90:10 and 85:15 were not significantly different from that of control. Furthermore, significant changes started to happen on pan bread with 20% modified porang flour substitution in which that of ratio 70:30 showing the lowest volume of 401.67±34.74 cc. Bread volume is a parameter often used in determining the qualities of bread loaf where higher bread volume with the same dough weight indicates higher quality and more consumer acceptance of the bread. As consumers use this parameter to value the worth of bread, baking industries needed to follow this trend in order to attract consumers to gain desirable economic benefits. Which is one of the reasons why bread volume is an important parameter in bread making [38].

From Figure 5, it shows that pan bread with ratio 100:0 exhibited similar (not significantly different) to those substituted breads up to 80:15 ratio, then the volume significantly decreased accordingly with the increasing substitution of modified porang flour. One of the most important factors in affecting bread volume is the amount of gluten present as it is responsible of trapping carbon dioxide forming in the dough and creating a network of air pockets of different sizes which gives off large volumes of bread [39]. The reduction in the percentage of wheat flour causes the bread loaf to have a decreased gluten content, causing less quantity and size of carbon dioxide bubbles to form in the interior of the bread and could not retain the carbon dioxide during proofing [40].



Note: Superscript notation i.e. different indicates significant difference (p≤0.05)
Fig. 5. Effect of wheat flour to porang flour ratios on pan bread volume

Starch is also an important factor in providing good volume of bread. In bread products, the amount of damaged starch affects the dough's functional characteristics. Upon reaching a certain point of broken starch will promote fermentation activity, yielding to a higher volume of bread. Meanwhile too little damaged starch will result in a low volume bread [41]. During baking, starch absorbs water which is available in the dough as gluten denatures and loses its water holding capacity. The absorbed water will result in swollen starches that interact together with gluten to produce rigid structure which increases gas retention in dough and in turn increases bread volume [28]. Bread volumes are also good indicators of other bread quality parameters such as the bread crumb. Bread volume with less volume indicates a dense and compact crumb, meanwhile bread volume with higher volume will possess light, soft and airy crumb [42].

3.9 Effect of ratios of wheat flour to chosen modified porang flour ratio on sensory attributes of pan bread

3.9.1 Scoring values

The scoring values of pan breads is displayed in Table 6. Statistical analysis revealed there was a significant effect (p≤0.05) of different ratios of wheat flour and treated porang flour on all parameters which are crust and crumb color, firmness, aroma, and taste of pan bread.

As shown in Table 6, crust color of pan bread made with ratio of 100:0 (2.62±0.31) and 70:30 (4.32±0.4) exhibited the lowest and highest scores, respectively, indicating that pan bread with ratio of 100:0 having the lightest crust color and yet similar (not significantly different) to those of 95:5 and 90:10, and pan bread with ratio of 70:30 having the darkest crust color. As mentioned earlier, the formation of crust color relies heavily on the content of reducing sugars and protein present in the dough. The substitution of wheat flour with modified porang flour results in different protein and reducing sugar content, therefore, explaining the different outcomes of crust color between each formulation [43].

Table 6. Scoring values of control and substituted pan bread

Ratio (Wheat Flour: Modified Porang Flour)	Parameter				
	Crust Color	Crumb Color	Firmness	Aroma	Taste
100:0	$2.62{\pm}0.31^{a}$	$4.58{\pm}0.16^{e}$	$2.68{\pm}0.07^{a}$	$1.67{\pm}0.05^{a}$	$1.53{\pm}0.14^{a}$
95:5	$3.22{\pm}0.21^{ab}$	$3.65{\pm}0.02^{d}$	$2.82{\pm}0.02^{ab}$	$2.25{\pm}0.07^{b}$	$1.88{\pm}0.12^{b}$
90:10	$3.17{\pm}0.42^{abc}$	$2.9{\pm}0.14^{c}$	$3.12{\pm}0.07^{bc}$	$2.55{\pm}0.02^{c}$	$2.47{\pm}0.09^{c}$
85:15	$3.65{\pm}0.12^{bcd}$	$2.62{\pm}0.02^{bc}$	$3.38{\pm}0.07^{cd}$	$2.87{\pm}0.05^{d}$	$2.9{\pm}0.04^{d}$
80:20	$3.57{\pm}0.33^{bc}$	$2.47{\pm}0.05^{b}$	$3.57{\pm}0.28^{de}$	$2.78{\pm}0.02^{d}$	$3.12{\pm}0.07^{d}$
75:25	$3.92{\pm}0.07^{cd}$	$2.08{\pm}0.26^{a}$	$3.85{\pm}0.07^{e}$	$3.07{\pm}0.14^{e}$	$3.43{\pm}0.09^{e}$
70:30	$4.32{\pm}0.4^{d}$	$1.93{\pm}0.09^{a}$	$4.97{\pm}0.19^{f}$	$3.65{\pm}0.12^{f}$	$4.07{\pm}0.09^{f}$

Note: Superscript notation i.e. different on each column indicates significant difference p≤0.05)

As for crumb color shown in Table 6, pan bread made with ratio of 100:0 (4.58±0.16) and 70:30 (1.93±0.09) exhibited the highest and lowest score, respectively, indicating that pan bread with ratio of 100:0 has the most yellow crumb color and pan bread, and that with ratio of 70:30 having the least yellow crumb color which also similar to that of 75:25. The color of crumb becomes darker and brown along with the increase of modified porang flour substitution. Similar results are found in previous research [44], that showed that darkening in crumb color happens due to the different content of proteins available in the dough, resulting in different effects of Maillard reaction. Besides that, originally, the modified porang flour has a lower lightness value than wheat flour resulting in darker crumb color as the substitution ratio increases.

For firmness shown also in Table 6, pan bread made with ratios of 100:0 (2.68±0.07) together with 95:5 ratio, and 70:30 (4.97±0.19) exhibited the highest and lowest values, respectively, indicating that pan bread with ratios of 100:0 and 95:5 exhibiting the softest bread texture, and pan bread with ratio of 70:30 the firmest bread texture. The increasing rigidity of pan bread with more substitution of modified porang flour might be due to the reduction of air-retention ability that is lost due to weaker gluten networks [45].

In terms of bread aroma (Table 6), pan bread made with ratio of 100:0 (1.67±0.04) and 70:30 (3.65±0.12) exhibited the lowest and highest score, respectively, indicating that pan bread with ratio of 100:0 has the least odd aroma, and pan bread with ratio of 70:30 the oddest aroma compared to other formulations. During baking step of bread, the contribution of protein to the development of bread aroma is important in the influence of bread sensory characteristics [43] (Korus et al., 2021).

As for bread taste (Table 6), pan bread made with ratio of 100:0 (1.53±0.14) and 70:30 (4.07±0.09) exhibited the lowest and highest scores, respectively, indicating that pan bread with ratio 100:0 has the least odd taste, and pan bread with ratio 70:30 having the oddest taste compared to other formulations. According to Choi and Peterson [46], aroma and taste are influenced by ingredients, enzymatic reactions occurring during dough fermentation, and thermal reactions during baking. Ingredients used in breadmaking, mainly wheat flour have distinct characteristics that might undergo several modifications during the breadmaking that might yield typical aroma and taste of bread.

3.9.2 Hedonic values

Hedonic values of pan breads partially substituted with HMT modified porang flour are shown in Table 7. Based on statistical analysis, there was a significant effect ($p \leq 0.05$) of different ratios of wheat flour and modified porang flour on all parameters which are crust and crumb color, firmness, aroma, taste, and overall acceptance of pan bread.

Table 7. Hedonic test result of pan bread

Ratio (Wheat Flour: Modified Porang Flour)	Parameter					
	Crust Color	Crumb Color	Firmness	Aroma	Taste	Overall
100:0	5.58 ± 0.21^{d}	5.9 ± 0.24^{e}	5.5 ± 0.09^{e}	5.58 ± 0.02^{d}	5.92 ± 0.12^{e}	6.02 ± 0.16^{f}
95:5	5.10 ± 0.04^{c}	5.05 ± 0.26^{d}	5.23 ± 0.24^{e}	5.28 ± 0.02^{d}	5.45 ± 0.02^{d}	5.38 ± 0.07^{e}
90:10	4.43 ± 0.14^{b}	4.18 ± 0.16^{c}	4.75 ± 0.24^{d}	4.6 ± 0.04^{b}	4.82 ± 0.12^{d}	4.82 ± 0.07^{d}
85:15	4.23 ± 0.04^{b}	3.8 ± 0.05^{bc}	4.33 ± 0.09^{c}	4.42 ± 0.02^{bc}	4.33 ± 0.05^{d}	4.23 ± 0.05^{c}

80:20	4.22±0.02^{b}	3.65±0.07^{b}	3.9±0.28^{b}	4.22±0.26^{c}	4.25±0.16^{c}	4.13±0.05^{bc}
75:25	3.52±0.07^{a}	3.12±0.07^{a}	3.75±0.02^{b}	4.15±0.02^{c}	3.92±0.16^{b}	3.90±0.09^{b}
70:30	3.3±0.24^{a}	2.83±0.28^{a}	2.85±0.07^{a}	3.67±0.33^{d}	3.23±0.38^{a}	3.12±0.16^{a}

Note: Superscript notation i.e. different on each column indicates significant difference p≤0.05)

As shown in Table 7, crust color of pan bread made with ratios of 100:0 (5.58±0.21), and both 70:30 and 75:25 ratios (3.3±0.24; 3.52±0.07) exhibited the highest and lowest values, respectively, indicating that pan bread with a ratio of 100:0 being the most acceptable and pan bread with ratios of 70:30 and 75:25 having the least acceptable crust color. The acceptance of crust color also decreases accordingly with the increased amount of modified porang flour substitution.

As for crumb color, pan bread made with a ratio of 100:0 (5.9±0.24), and both 70:30 and 75:25 ratios (2.83±0.28; 3.12±0.07) exhibited the highest and lowest values, respectively, indicating that pan bread with ratio of 100:0 being the most acceptable and pan bread with 70:30 and 75:25 ratios having the least acceptable crumb color. The acceptance of crumb color also decreases orderly with the amount of modified porang flour substitution, as higher ratio of substitution yielded in darker bread crumb color.

For firmness (Table 7), pan bread made with ratio of 100:0 (5.5±0.09) and 70:30 (2.85±0.07) exhibited the highest and lowest values, respectively, indicating that pan bread with ratio of 100:0 being the most acceptable and pan bread with 70:30 ratio having the least acceptable bread firmness. The acceptance of bread firmness also decreased accordingly as the amount of modified porang flour substitution increased. A higher ratio of substitution yielded in a more rigid bread texture. However, in general, bread with softer texture is more preferred by the panellist and consumers [45] (Wang et al., 2021).

For aroma also shown in Table 7, pan bread made with ratio of 100:0 (5.58±0.02) and 70:30 (3.67±0.33) exhibited the highest and lowest values, respectively, indicating that pan bread with ratio of 100:0 being the most acceptable and pan bread with ratio of 70:30 having the least acceptable aroma. The acceptance of aroma also decreased as the amount of modified porang flour substitution increased where a higher ratio of substitution yielded odder aroma.

In terms of taste, it is also shown a similar pattern where pan bread made with ratios of 100:0 (5.92±0.12) and 70:30 (3.23±0.38) exhibited the highest and lowest values, respectively, indicating that pan bread with ratio of 100:0 the most acceptable and pan bread with ratio of 70:30 having the least acceptable taste. The acceptance of taste also decreased accordingly as the amount of modified porang flour substitution increased and showing that a higher ratio substitution resulted in odder taste.

Overall acceptance of pan bread shows that pan bread made with ratio of 100:0 (6.02±0.16) and 70:30 (3.12±0.16) exhibited the highest and lowest values, respectively, indicating that pan bread with ratio of 100:0 being the most acceptable and pan bread with ratio of 70:30 having the least overall acceptance.

3.9.3 Selected pan bread based on physicochemical and organoleptic characteristics

The best formulation of pan bread was selected based on characteristics such as bread volume and hardness. It is based on these categories pan bread with ratios of 95:5 and

85:15 showed no significant difference with the control, however by considering their absolute values, pan bread with ratios of 95:5 and 85:15 showed higher values of hardness of 845.24±40.94 and 1131.46 ±79.40, respectively, and lower values of volume of 846.67±64.78 and 805.83±29.23, respectively, than that of the control's hardness (795.095 ±54.88) and volume (907.50 ±56.46). Pan bread with a ratio of 90:10, however, showed the closest comparable value of hardness (824.364 ±52.3) and volume (887.5 ±40.59) to those of the control.

Therefore, pan bread with the ratio of 90:10 was selected as the best formulation based on its physicochemical characteristics. In terms of overall organoleptic acceptance, pan bread with the ratio 90:10 (4.82±0.07) showed closer value to that of the control (6.02±0.16) although the closest value would be that of the ratio 95:5, it is inferior to that of the ratio 90:10 with regards to the main parameter used for selection i.e. hardness and volume. Thus, pan bread with the ratio 90:10 was analyzed for its chemical composition.

Chemical composition of the control and selected (90:10 ratio) pan bread

Chemical composition of pan bread with ratios of 100:0 (control) and 90:10 was shown in Table 8. Statistical analysis of the chemical composition of of the control and selected (90:10 ratio) pan bread was done using independent t-test to compare the analyzed components between the two pan breads.

Chemical composition of pan breads with the ratio of 100:0 and 90:10 can be seen in Table 8. Based on the t-test there was no significant difference ($p \leq 0.05$) between 100:0 (control) and 90:10 ratios pan breads in terms of fat, protein, ash and carbohydrate with the exception of moisture content of pan breads. This indicates that both pan breads have similar compositional quality.

Table 8. Chemical composition of pan bread

Composition	**Amount (%, db)**	
	100:0 (Control)	**90:10**
Moisture	29.83±0.57^{a}	32.47±0.73^{b}
Protein	17.43±0.66^{a}	16.27±0.31^{a}
Fat	8.68±1.73^{a}	8.52±1.94^{a}
Ash	1.47±0.08^{a}	1.67±0.15^{a}
Carbohydrate	42.58±0.91^{a}	41.07±2.59^{a}

Note: Superscript notation i.e. different indicates significant difference ($p \leq 0.05$)

4 Conclusions

The modification of porang flour using Heat Moisture Treatment (HMT) and the making of pan bread using the sponge-dough method has been successfully done. Porang flour modified at 80°C for 10 hrs exhibited the highest swelling power of 8.05±0.58 g/g and was selected for incorporation in to pan bread formulation. Pan bread partially substituted with 10% of HMT modified porang flour and prepared using the sponge-dough method exhibited the most comparable results to the control pan bread in terms of its physicochemical characteristics such as volume and hardness. Therefore, it was chosen as the best formulated pan bread and was analyzed for its chemical composition. Pan bread with this substitution ratio of 10% did not show significant difference with control pan bread in terms of chemical composition except for moisture content. Pan bread volume is a key parameter for successful substitution which is shown by pan bread with substitution ratio of 90:10 with volume 887.5±40.59 cc. Therefore, partially substituted pan bread using HMT modified flour with ratio of 90:10 may be recommended to food industries.

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