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FULL PAPER

Functional and rheological properties of mixed flour from mangrove fruit of *Bruguiera gymnorrhiza* flour and wheat flour

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Abstract

In order to yield influential information on the most recommended use of BGF, which so far still questioned, this preliminary study was aimed to investigate the physicochemical and functional properties of mixed flour of BGF and wheat flour (WF). A total of nine mixtures of WF: BGF of (90%:10%; 80%:20%; 70%:30%; 40%:60%; 50%:50%; 40%:60%; 30%:70%; 20%:80%; 10%:90%) were produced, where single WF and BGF were used as controls. This research revealed the different amount of BGF and wheat flour in the mixed flour showed the significantly different value of functional and rheological properties attributes, such as bulk density, CI, HR, WAI, WSI, SP, OAC, peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity and peak time. We have inferred to some previous studies and speculated that the difference in functional and rheological properties could be caused by the different amylose and amylopectin amount in the mixed flour. As far as we know that this present study was the first study on the mixed flour of BGF and wheat flour, therefore we suggested a more comprehensive study such as investigation of baking performance and bread qualities.

1. Introduction

Bruguiera gymnorrhiza flour (BGF) is a growing mangrove species that is widely distributed in the tropics and occurs along the east coast of Africa from just north of East London (Eastern Cape) to Somalia, Madagascar and the Indian Ocean islands, the south Asian coast from Iran to China, north Australia and numerous tiny (and larger) islands in the Pacific (South African National Biodiversity Institute). In fact, this species has been utilized by many coastal people to some value-added products such as flour, crackers and flatbread or biscuit. Our observation prior this present study represented that the particle size of BGF produced by people was relatively too large; consequently, BGF could not be mixed well with other ingredients in bread making, which further causes poor consistency of the final product. This problem is due to the lack of scientific proof on the functional and rheological characteristics on the mixed flour. A previous study by Amin *et al.* (2018) shows that BGF is cohesive, has a small amount of protein, and is suggested to be mixed with wheat flour with a low protein amount for biscuit making. Generally, there are some ideas of mixing different flour such as fortification purposes, cost-effectiveness, emerging supply chain problem towards wheat flour and intensify the customer preferences (Khetarpaul and Goyal, 2009; Udofia *et al.,* 2013; Iwe *et al*., 2016).

Previous studies demonstrate that the different flour mixed in the bread recipe could yield different physicochemical, functional and sensory characteristics of the final bread produced (Chandra *et al*., 2015), where generally bread producers are willing to produce bread with high customer preferences. Monthe *et al*. (2019) and Ren *et al*. (2020) demonstrate that the different final characteristics of the bread produced from different flour are caused by the different functional and rheological properties of the blended flour in the recipe. Therefore, this idea became the main approach to performing this present study.

Functional properties of the flour are related to density, swelling capacity, water absorption index (WAI), water solubility index (WSI), oil absorption capacity (OAC), emulsifying activity and foaming

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capacity (Prajapati *et al*., 2015; Menon *et al*., 2015), while rheological properties are related to peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature (Jariyah *et al.,* 2014; Gerits *et al.,* 2015; Shafie *et al.,* 2016). The rapid visco-analyzer (RVA) is a robust method which is incredibly useful in the flour studies. This method possesses by mimicking the cooking process of a cereal when a flour-water suspension is subjected to a heat-hold-cool-hold temperature cycle (Chen *et al*., 2008). Our present study aims to investigate the functional and rheological properties of mixed flour from wheat flour and BGF.

2. Material and methods

2.1 Materials

Two main flour were used in this study vis. wheat flour and *Bruguiera gymnorrhiza* flour (BGF). Wheat flour with the total fat, protein, carbohydrate, starch, amylose, and the ratio of amylose to starch of 1.00% (w/w), 10% (w/w), 76% (w/w), 63.41±0.11% (w/w), 23.85±0.41% (w/w) and 24:76 respectively was obtained from PT. Bogasari Tbk. Indonesia. BGF with the total starch, amylose, and ratio of amylose to starch of 59.15±1.52% (w/w), 34.30±2.55% (w/w) and 34:66 respectively was prepared by Amin *et al.* (2018) with a very slight modification, where the milling was conducted more intensively by using a stainless steel flour miller FCT Z100. Mixed flours were prepared by a physically mixing of two different flours until fully homogenous, with eventually nine combinations were made with two single flours such as wheat flour and BGF which were used as controls (Table 1).

Table 1. Formulation of mixed flour

Code	Wheat flour (%w/w)	BGF (%w/w)
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50
G	40	60
H	30	70
I	20	80
J	10	90
K	0	100

2.2 Proximate composition determination

Moisture content, fat content, amylose content, total starch was analyzed using the reference methods of AOAC (2007). Carbohydrate content was determined by using by difference method.

2.3 Determination of density, expansion index, Carr index and Hausner ratio

The density was determined according to a method of Okezie and Bello (1988) which was prior used by Amin *et al.* (2018). Hausner ratio and Carr index were analyzed using this following equation:

$$\text{Hausner ratio (HI)} = \frac{\text{Tapped density (g/mL)}}{\text{Bulk density (g/mL)}} \quad (1)$$

$$\text{Carr Index (CI)} = \frac{\text{Tapped density (g/mL) - Bulk density (g/mL)}}{\text{Tapped density (g/mL)}} \times 100 \quad (2)$$

Flour with HR <1.2, 1.2<HR< 1.4, >1.4 is classified as low, intermediate, high cohesive group respectively, while CI < 15, 15< CI < 20, 20< CI < 35, > 45 is classified as very good, fair, bad, very bad respectively

2.4 Gel hydration properties

Gel hydration properties were performed according to Toyokawa *et al.* (1989). Approximately 100 mg of flour (W_i) was dispersed in 2.0 mL of water and then heated at the temperature of 90°C for 10 mins in a thermostat water bath. The suspension was then cooled at the temperature of 4°C, centrifuged at 3,500 rpm for 15 mins. The supernatant was decanted and then evaporated with an oven at the temperature of 105°C until the sample shows a persistent weight (W_s). The residue (lower fraction of centrifuged sample) was also weighed (Wr). The result was calculated according to the following equations:

$$\text{WAI}\left(\frac{g}{g}\right) = \frac{Wr}{Wi} \quad (3)$$

$$\text{WSI}\left(\frac{g}{g}\right) = \frac{Ws \times 100}{Wi} \quad (4)$$

$$\text{SP}\left(\frac{g}{g}\right) = \frac{Wr}{Wi - Ws} \quad (5)$$

2.5 Oil absorption capacity (OAC)

A 100 mg of flour was weighed (W_i), mixed with 1 mL vegetable oil, then the mixture was vortexed for 2 mins with maximum velocity. The mixture was then centrifuged at 3000 rpm for 10 mins, the supernatant was decanted. The tube containing residue was then inverted to remove remaining oil in the flour, furthermore the residue was weighed (W_r) and then the OAC was determined according to the following equation.

$$\text{OAC}\left(\frac{g}{g}\right) = \frac{Wr}{Wi} \quad (6)$$

2.6 Rheological properties determination

Rheological properties were determined by using a Rapid Visco Analyzer (RVA-4, Newport Scientific Pty Ltd., Warriewood, NSW2102, Australia). A 2.5 g of flour was dispersed in 25 mL water in an aluminum can and then the suspension was centrifuged at 160 RPM at the temperature of 50˚C for 1 min. The heating was then raised to 95˚C within 7.5 mins and held at 95˚C for 5 mins, and then cooled back to 50˚C within 7.5 mins and

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held at 50˚C for additional 2 mins (Rahmawati *et al.,* 2014).

2.7 Statistical analysis

One-way analysis of variance (ANOVA) furthered by Tukey's HSD (honestly significant difference) were carried out by using a Statistical Software SPSS 16. The statistical analyses were performed with a confidence level of 95%.

3. Results and discussion

3.1 Moisture content and functional properties of mixed flour from wheat flour and BGF

The analysis of variance showed that moisture content within observed flours was not affected by the formulation (Table 2). This happened because the moisture content between control wheat flour and BGF was quite similar. While all functional properties variables, apart from tapped showed a significant difference.

Table 2. Analysis of variance (ANOVA) results

Variables	F-value	*p-value
Moisture content	1.661	0.154
Functional properties		
Tapped density	1.187	0.351
Bulk density	53.288	0.000
CI	10.928	0.000
HR	18.426	0.000
WAI	4.004	0.003
WSI	8.161	0.000
SP	2.923	0.017
OAC	23.293	0.000
Rheological properties		
Peak viscosity	1.69E+03	0.000
Trough viscosity	271.057	0.000
Breakdown viscosity	1.02E+03	0.000
Final viscosity	949.392	0.000
Setback viscosity	527.423	0.000
Peak time	234.242	0.000
Pasting temperature	1.387	0.299

*A significant p-value was (≤0.05)

According to Table 3, the mixed flour with more BGF relatively had lower tap density because BGF, while the highest cohesiveness and flow-ability were mixed flour "C" and "I" respectively. Particle size and the ratio of amylase and amylopectin were the crucial factors affecting these characteristics, where amylopectin has a bigger molecular weight than amylose. Abdullah and Geldart (1999) state that flour with good flow-ability could be produced by reducing the consolidation ability with each other. Fitzpatrick (2005) states that the surface area of the flour affects the particle contact, cohesive force and frictional forces where flour with the lower particle size will more attractive to contact with each particle to resist flow. This study suggested that in the industrial application, mixed flour with a high bulk density would relatively require spaces during storage.

Gel hydration is a highly important variable in the future application of mixed flours in this present study. WSI, WAI and swelling power has correlation each other, where according to the equation the value of swelling power depends on the number of water-soluble fractions and the capacity of the flour in absorbing water during the gelatinization. This research showed that single BGF had lower swelling power than wheat flour, and the incorporation of BGF in mixed flour relatively decreased the swelling power of the mixed flour (Table 3). According to Bhat *et al.* (2016), gel hydration properties of the flour is related to the ratio of amylose and amylopectin, where flour with more amylopectin binds more water than flour with lower of amylopectin. The increase of WSI when more BGF incorporated in the mixed flour could demonstrate that BGF theoretically had more water-soluble fraction such as tannin (Girard *et al.,* 2018), tannin can interact with a protein of the flour where the interaction decreases the surface hydrophobicity of flour protein (gluten). Wang *et al.* (2015) state that the decreasing of surface hydrophobicity of the gluten because of tannin-induced gluten polymer aggregation. According to Yang *et al.* (2017), the decreasing of surface hydrophobicity of flour protein can influence the capacity of the protein in absorbing water and oil.

The oil absorption capacity (OAC) is considered important for the future use of mixed flour in this study, as bakery products contain some butter to yield palatable bread. This study represented that BGF relatively increased the oil absorption capacity of the mixed flour (Table 3). Gerits *et al.* (2015) reveal that amylose can bind lipid more than amylopectin, which means the flour containing more amylose tends to bind more lipid than flour with less amylose content. Niba *et al.* (2001) state that flour having high oil absorption capacity is suitable to be used in baking because it can improve mouthfeel and maintain the flavor of the baking product.

3.2 Rheological properties of mixed flour

Based on the statistical analysis, most rheological properties were significantly affected by the ratio of wheat flour to BGF, although only pasting temperature was not significantly affected by the formulation (Table 2).

According to Table 4 peak viscosity of the mixed flour reduced when BGF was incorporated, this finding was speculated due to the reduction of theoretical protein of the mixed flour as the consequence of BGF

Table 3. Moisture content and functional properties of mixed flour of wheat flour and BGF

Code	Moisture content	Tap Density (g/mL)	Bulk Density (g/mL)	HR	WAI (g/g)	WSI (g/100g)	SP (g/g)	OAC (g/g)	CI
A	12.54±0.77^{ab}	0.83±0.01^{a}	0.62±0.01^{b}	1.35±0.04^{cd}	10.61±0.10^{a}	4.44±0.40^{cb}	11.11±0.15^{a}	1.92±0.02^{d}	26.00±2.00^{cd}
B	11.95±0.46^{ab}	0.80±0.00^{ab}	0.63±0.02^{b}	1.28±0.03^{ed}	9.97±0.65^{abc}	3.10±0.29^{ef}	10.30±0.70^{abcd}	2.03±0.02^{b}	22.00±1.73^{ed}
C	11.25±1.21^{b}	0.79±0.12^{ab}	0.49±0.02^{c}	1.61±0.23^{a}	10.10±0.89^{abc}	3.99±1.63^{cde}	10.53±1.10^{abc}	2.06±0.03^{a}	37.23±8.41^{a}
D	12.02±0.33^{ab}	0.79±0.01^{ab}	0.51±0.01^{cd}	1.56±0.01^{ab}	10.48±0.56^{ab}	2.84±0.29^{f}	10.80±0.60^{abc}	2.09±0.03^{a}	35.80±0.43^{a}
E	12.86±1.38^{a}	0.78±0.01^{ab}	0.52±0.02^{cd}	1.48±0.02^{bc}	10.65±0.78^{a}	3.24±0.40^{def}	11.00±0.77^{ab}	2.00±0.01^{bc}	32.47±0.88^{ab}
F	11.77±0.40^{ab}	0.76±0.02^{ab}	0.54±0.01^{d}	1.42±0.01^{cd}	9.46±0.65^{cd}	3.85±0.26^{cdef}	9.84±0.66^{cd}	2.00±0.02^{bc}	29.48±0.56^{cb}
G	12.33±1.05^{ab}	0.76±0.01^{b}	0.54±0.01^{b}	1.41±0.03^{cd}	9.54±0.08^{bcd}	4.31±0.30^{bcd}	9.97±0.06^{bcd}	1.97±0.01^{c}	29.05±1.49^{cb}
H	12.27±0.31^{ab}	0.75±0.04^{b}	0.53±0.03^{d}	1.41±0.01^{cd}	9.31±0.69^{cd}	4.23±0.49^{bcd}	9.72±0.76^{cd}	1.99±0.01^{c}	29.26±0.51^{cb}
I	11.27±0.37^{b}	0.80±0.01^{ab}	0.66±0.01^{a}	1.22±0.01^{ef}	8.74±0.15^{d}	5.80±0.39^{a}	9.28±0.18^{d}	1.99±0.00^{c}	17.82±0.49^{e}
J	11.14±0.45^{b}	0.78±0.01^{ab}	0.58±0.01^{c}	1.34±0.02^{cde}	9.48±0.17^{cd}	5.62±0.29^{a}	10.05±0.15^{abcd}	1.94±0.01^{d}	25.61±1.22^{cd}
K	11.92±0.34^{ab}	0.78±0.02^{ab}	0.68±0.02^{a}	1.17±0.05^{f}	9.29±0.25^{cd}	5.29 ±0.45^{ab}	9.81±0.22^{cd}	2.03±0.02^{b}	12.67±3.79^{f}

Values were expressed as mean±SD of triplicates. Values with different superscripts within the column indicate a significant difference ($p<0.05$).

Table 4. Rheological properties of the observed flour

Formulation	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)	Peak time (min)	Pasting temperature (°C)
A	2110.00^{a}	1111.50^{b}	998.50^{a}	2399.50^{a}	1288.00^{a}	9.13^{b}	84.65^{a}
B	2014.00^{b}	1161.50^{a}	852.50^{b}	2178.50^{b}	1017.00^{b}	8.87^{c}	84.93^{a}
C	1875.50^{c}	1113.00^{b}	762.50^{c}	1977.50^{d}	864.50^{d}	8.70^{d}	84.53^{ab}
D	1879.50^{c}	1123.50^{b}	756.00^{c}	1930.00^{e}	806.50^{e}	8.50^{e}	83.70^{ab}
E	1802.50^{d}	1114.50^{b}	688.00^{d}	2143.00^{c}	1028.50^{b}	8.47^{e}	79.16^{b}
F	1558.00^{e}	1032.50^{c}	525.50^{e}	1959.50^{ed}	927.00^{c}	8.24^{f}	81.10^{ab}
G	1396.00^{f}	1020.00^{c}	376.00^{f}	1857.00^{g}	837.00^{de}	8.20^{f}	82.85^{ab}
H	1263.50^{g}	1001.50^{e}	262.00^{g}	1765.00^{f}	763.50^{f}	8.20^{f}	82.70^{ab}
I	1034.50^{i}	925.50^{e}	109.00^{i}	1504.00^{h}	578.50^{g}	8.53^{e}	83.53^{ab}
J	1025.00^{i}	924.00^{e}	101.00^{i}	1375.50^{i}	451.50^{b}	9.13^{b}	84.45^{ab}
K	1100.00^{h}	951.50^{d}	148.50^{h}	1270.00^{j}	318.50^{i}	9.27^{a}	85.15^{a}

Values are means of duplicate testing. Values with different superscript indicate statistical significance.

incorporation. Protein should be responsible for trapping water; meanwhile, the content was practically reduced due to incorporation (Hamer and Hoseney, 1998). Furthermore, peak viscosity is related to the water-binding capacity of the flour, where reduction of peak viscosity indicates declining swelling or gelatinization power (Beta and Corke, 2001). More specifically, water binding capacity also depends on the ratio of amylose to amylopectin, where amylopectin has a better capability in binding water.

Apart from peak viscosity, final, setback, breakdown viscosity relatively declined when BGF was incorporated. This phenomenon could be connected to a prior study by Sopade *et al.* (2006) that states the capability of forming gel affects the final viscosity. Hence, this study concluded that the more BGF, the lower amount of gels formed in the mixed flour. Setback viscosity is related to the flour retro-gradation where flour with low setback viscosity implies the high resistance to retro-gradation (Ikagewu *et al.,* 2009). According to Ikegwu *et al.* (2009), flour with low setback viscosity has resistance in starch retro-gradation. A prior study carried out by Jariyah *et al.* (2014) suggests that flour with high resistance in starch retro-gradation is recommended to be incorporated into baked food ingredients.

The declining of breakdown viscosity was relevant to Corke *et al.* (2017), showing that flour paste with low breakdown viscosity has low hydration ability, swelling power and high sear resistance. This present study also revealed that the incorporation of BGF into mixed flour relatively reduced WAI and SP. The lower breakdown viscosities may be due to restricted swelling of the starch granules, which increase the tendency of the hydrophilic chain of flour containing fiber to bind with hydrogen bonds of the water. Furthermore, the reduced water availability for starch granules occurs.

The pasting temperature was different within composition where according to Fitzgerald *et al.* (2003). The decreasing of moisture content increases of pasting temperature, suggesting that water affects the rheological responses to stirring of the components of the gelatinized and swollen flour. Shafie *et al.* (2016) state that the higher pasting temperature indicates the resistance against swelling in the ingredient, which could be correlated to the amount of amylose and amylopectin in the flour.

To the best of our knowledge, the present work is the first study to focus on the characterizing the mixture of BGF with wheat flour, which meant a more comprehensive study on the mixed flour is necessary such investigation of baking performance and bread qualities.

4. Conclusion

This research revealed the different amount of BGF and wheat flour in the mixed flour showed the significantly different value of functional and rheological properties attributes, such as bulk density, CI, HR, WAI, WSI, SP, OAC, peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity and peak time. We have inferred to some previous studies and speculated that the difference in functional and rheological properties could be caused by the different amylose and amylopectin amount in the mixed flour. As far as we know that this present study was the first study on the mixed flour of BGF and wheat flour, therefore we suggested a more comprehensive study such as investigation of baking performance and bread qualities.

Conflict of interest

There is no conflict of interest

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