Full Length Article

Functional and rheological properties of composite flour from sweet potato, maize, soybean and xanthan gum

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KEYWORDS
Composite flours; Maize; Soybean; Sweet potato; Xanthan gum

Abstract Sweet potato flour (SP), maize starch (MS), and soybean flour (SF) blends were prepared in different proportions like: 60SP/20MS/19.5SF; 50SP/30MS/19.5SF; 40SP/40MS/19.5SF; 50SP/20MS/29.5SF; 40SP/20MS/29.5SF; and 30SP/40MS/29.5SF. The constant percentage of xanthan gum at 0.5% was added to each blend. Functional and rheological properties of the composite flour were examined and compared with wheat flour as control. Oil absorption index was not significantly different (P > 0.05) among the six blends of composite flour and wheat flour. As increasing of soybean flour levels, swelling power, and pasting viscosity of composite flours decreased, specific volume of bread also decreased as decreasing of soybean flour level in composite flours, but the firmness of bread increased. Physical and sensory analysis showed that composite flour with the proportion of sweet potato flour 40%, maize starch 40%, soybean flour 19.5% and xanthan gum 0.5% yielded acceptable breads.

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1. Introduction

Production of baked products such as bread, cakes, buns, doughnuts, and biscuit generally used wheat flour, as a result of the nature and functional properties of the wheat flour proteins. But local climatic conditions in tropical countries such as Indonesia are not suitable for profitable wheat production, and consequently, Indonesia has been completely dependent on imported wheat for manufacture of baked products. For this reasons, the research focused on composite flour from local crops to replace wheat. Composite flour was defined as a mixture of several flours obtained from roots, tubers, cereals and legumes with or without the addition of wheat flour (Adeyemi and Ogazi, 1985; Shittu et al., 2007). Composite flours have been used extensively and successfully in the production of baked foods. Some studies were reported on the use of cereal-tuber-legume combination for the production of various products (Akubor and Ukwuru, 2005; Oladunmoye et al., 2010). It can be deduced from these reports that the qualities of product depend on the proportional composition

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of the composites and flour properties (Oladunmoye et al., 2010). Composite flour had a few advantages for developing countries such as Indonesia as it reduces the importation of wheat flour and encourages the use of domestic agricultural products as flour (Hugo et al., 2000).

Sweet potato ranks the seventh most important food crop in the world and fourth in tropical countries (FAOSTAT, 2004). It is a low input crop, wide production geography, adaptability to marginal condition, short production cycle, high nutritional value and sensory versatility in terms of flesh colors, taste and texture. Depending on the flesh color, sweet potatoes are rich in β-carotene, anthocyanins, total phenolics, dietary fiber, ascorbic acid, folic acid and minerals (Woolfe, 1992; ILSI, 2008). Although sweet potato had many positive attributes and was cheaper than other crops, this abundant resource is still poorly utilized. The development of appealing processed products from sweet potatoes will play a major role in raising awareness on the potential of the crop.

Corn is considered as one of the principle crops in Indonesia and its production is increasing yearly; however, it is mainly used for animal and poultry feeding, in spite of the shortage in the cereal-based foodstuffs. Soybean is an excellent source of protein (35–40%), rich in calcium, iron, phosphorus and vitamins, and also the only source of all the essential amino acids (Ihekonye and Ngoddy, 1985). Soybean proteins are rich in lysine but deficient in sulfur containing amino acids, whereas cereal proteins are deficient in lysine, but have adequate amounts of sulfur amino acids (Eggum and Beame, 1983). Addition of soybean flour to cereal based products could be a good option to provide better overall essential amino acid balance, helping to overcome the world protein calorie malnutrition problem (Livingstone et al., 1993). Soybean flour and soybean protein have been used as composite flour in the production of bread (Dhingra and Jood, 2001; Basman et al., 2003; Ribotta et al., 2004; Sanchez et al., 2004; Moore et al., 2006), cookies and biscuit (Shrestha and Noomhorm, 2002; Akubor and Ukwuru, 2005), and pasta (Ansari et al., 2013; Doxastakis and Papa georgiou, 2007).

It is important to note that baked products such as bread similar to wheat bread cannot be obtained from non-wheat flour, due to deficiency of gluten, a viscoelastic protein. Gluten in wheat flour has a fundamental role in bread making, as it is an essential structure-building protein that provides viscoelasticity to the dough, good gas-holding ability and good crumb structure of the resulting baked product (Gallagher et al., 2003). Addition of hydrocolloids such as xanthan gum is the most important approaches developed to mimic the properties of gluten in gluten-free bakery products (Moore et al., 2006; Lazaridou et al., 2007; Arendt et al., 2008; Alvarenga et al., 2011). Xanthan gum is an extracellular polysaccharide produced by bacterium Xanthomonas campestris (Achayuthakan and Supantharika, 2008). It is commonly used with emulsifiers to develop non-gluten bread, bread rich in proteins, bakery fillings, syrup glazings, desserts and milk products, and cakes, to stabilize emulsions and to improve stability of frozen dough at concentration of 0.1–0.25% (Guarda et al., 2004; Gomez et al., 2007; Arocas et al., 2009; Makri and Doxastakis, 2006).

The objective of this research was to study the effect of proportion of sweet potato flour, maize starch, and soybean flour for the production of composite flour and applying the hydrocolloid xanthan gum compared with wheat flour (as control).

2. Materials and methods

2.1. Materials

White tuber varieties of sweet potato and anjasmoro variety of soybeans are obtained from local market in Medan. Commercial maize starch and wheat flour procured from PT.Budi Makmur Perkasa Indonesia and PT.Indofood Sukses Makmur Thb, Indonesia, respectively. Xanthan gum (G1253, Sigma–Aldrich USA) was procured from PT.Elo Karsa Utama (Jakarta, Indonesia). Other ingredients for baking bread were purchased from a local market in Medan, Indonesia.

2.2. Preparation of sweet potato flour

Sweet potato tubers were washed, peeled and cut into thin slices, spread in a tray and was oven dried at 60 °C for 10 h and after which it was milled into flour. The flours were screened through a 80 mesh sieve, and then stored in polyethylene bags before using.

2.3. Preparation of full fat soybean flour

Soybean grains were selected, washed and soaked into water for 6 h and then boiled in pressure cooker for 5 min. They were removed, dehulled and dried in the oven at 50 °C for 24 h after which they were ground into flour in an electric grinder. The flour was sieved through 80 mesh sieve. The flour samples were kept in airtight container before using. Packaging of flour samples differs between sweet potato and soy bean, because of the higher fat content in soy flour, so it is necessary to be in airtight container.

2.4. Composite flour preparation

The six different intervals of sweet potato flour, maize starch, and soybean flour (Table 1) are used in composite flours. Xanthan gum was added to the composite flours at 0.5% by total weight. Sweet potato flour (SPF) was blended with maize starch (MS), soybean flour (SF) and xanthan gum (XG) by using a mixer. The composite flour samples were stored in airtight container. Ingredient and composite flour samples were analyzed for functional and rheological properties. Wheat flour (WF) was used as control flour.

2.5. Functional properties of composite flours

The functional properties of individual and composite flour such as water absorption index (WAI), oil absorption index

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Different treatment used to prepare composite flour.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>Sweet potato flour (%)</td>
</tr>
<tr>
<td>$T_1$</td>
<td>60</td>
</tr>
<tr>
<td>$T_2$</td>
<td>50</td>
</tr>
<tr>
<td>$T_3$</td>
<td>40</td>
</tr>
<tr>
<td>$T_4$</td>
<td>50</td>
</tr>
<tr>
<td>$T_5$</td>
<td>40</td>
</tr>
<tr>
<td>$T_6$</td>
<td>30</td>
</tr>
</tbody>
</table>

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(OAI), swelling power, and baking expansion were determined by standard methods. WAI and OAI were determined according to the methods of Niba et al. (2001). Flour samples (1 g) were suspended in 5 ml of water (for WAI) or vegetable oil (for OAI) in a centrifugal tube. The slurry was shaken on a platform tube rocker for 1 min at room temperature and centrifuged at 3000 rpm for 10 min. The supernatant was decanted and discarded. The adhering drops of water were removed and reweighed. WAI and OAI were expressed as the weight of sediment/initial weight of flour sample (g/g).

The swelling power of flour was determined based on a modified method of Leach et al. (1957). Approximately 0.1 g of sample was transferred into a weighed graduated 50 ml centrifuge tube. Distilled water was added to give a total volume of 10 ml. The sample in the tube was stirred gently by hand for 30 s at room temperature, and then heated at 60 °C for 30 min. After cooling to room temperature, the samples were centrifuged for 30 min at 3000 rpm. The weight of sediment was recorded.

The measurement of baking expansion uses the method of Demiate et al. (2000) with a little modification. A total of 24 g of flour samples was partially cooked by the addition of 30 ml of boiling de-ionized water over the mass. The blend was homogenized to produce dough that was molded and baked in an electric oven at 200 °C for 20 min. Each of the baked dough was weighed, and made impermeable by robbing paraffin and their volumes were determined on graduated cylinders as the volume of water was displaced. The expansion was obtained by dividing volume by weight and was expressed as specific volume (ml/g).

2.6. Rheological properties of composite flours

Rheological properties of WF, SPF, MS and composite flour were evaluated with Rapid Visco Analyzer (RVA, Model Tecmaster Newport Scientific, Australia). A suspension of 3 g (14% w.b.) of flour in 25 g of distilled water underwent a controlled heating-and-cooling cycle under constant shear where it was held at 50 °C for 1 min, heated from 50 to 95 °C at 6 °C/min, and held at 95 °C for 5 min. The following data were recorded: pasting parameters of time from onset of pasting to peak viscosity (P time); temperature at which peak viscosity was reached (P temp); peak viscosity (PV); viscosity at the end of holding time at 95 °C (HPV); breakdown (BD) = PV–HPV; viscosity at the end of the hold time at 50 °C (CPV); setback viscosity (SB) = CPV–HPV, stability ratio (SR) = HPV/PV; and setback ratio (SBR) = CPV/HPV.

2.7. Bread preparation and evaluation

The six blends of composite flour were baked into bread using straight dough method (Chauhan et al., 1992). A total of 100 g of composite flours was mixed with 2 g yeast, 8 g sugar, 10 g skim milk powder, 1.5 g salt, and 10 g shortening in a kitchen mixer by adding 65–75 ml water for 2 min at low speed (speed setting: 1), and for 8 min at medium speed (speed setting: 2) until the dough was developed. In order to obtain approximately equal consistency of the dough from each of the composite flour, the amount of water added is varied. After mixing, the dough was covered with a kitchen cloth and left to proof for 10 min, and subsequently, the dough was kneaded and left to proof again for 15 min at room temperature. The dough was then rounded, placed into greased pans and fermented at room temperature (28 °C) for 1 h, and finally baked at 190 °C for 25 min in an electrical oven. The resulting bread samples were allowed to cool to room temperature and used for bread volume, texture, and sensory analysis.

The specific volume of bread was determined by a modification of the rapeseed replacement method according to the AACC method 10-05.01 (AACC, 2000), using sesame seed instead of rapeseed. Loaf volume was measured by sesame seed displacement immediately after removal from the oven and weighing. Loaves were placed in a container of known volume into which sesame seed were run until the container was full. The volume of seed displaced by the loaf was considered as the loaf volume. Loaf specific volume (SV) was calculated according to the following:

\[ \text{LSV} = \frac{\text{loaf volume (ml)}}{\text{loaf weight (g)}} = \frac{\text{ml}}{\text{g}} \]

Bread texture was measured as the resistance to an applied shear force using Universal Testing Machine (UTM). Force required to attain a given deformation was measured as F max (in Newton).

A sensory evaluation was also conducted to evaluate aroma, taste, texture, and crumb color of the bread sample. The bread samples were sliced into pieces uniform thickness and served with water. Fifteen semi trained panelists were randomly selected from students of Department of Food Science and Technology University of Sumatera Utara, to perform the evaluation. Panelists evaluated bread samples on a 5 point hedonic scale quality analysis with 5 = liked very much, 4 = liked, 3 = neither liked nor disliked, 2 = disliked, 1 = disliked very much.

2.8. Data analysis

Data using completely randomized design were analyzed using SAS Version 9.2 for windows. The data reported in all tables are an average of triplicate observations subjected to one-way analysis of variance (ANOVA). Differences between the ranges of the properties were determined using the method of Least Significant Difference (LSD) tests at 95% confidence level (\( P < 0.05 \)).

3. Results and discussion

3.1. Functional properties of composite flour

The results of the water and oil absorption index are presented in Fig. 1. All of composite flours displayed stronger affinity for water than oil, but wheat flour has stronger affinity for oil than water. In general, water absorption index among the composite flours did not differ significantly, but it was higher than wheat flour. Water absorption index is an important processing parameter and has implications for viscosity. It is also essential in bulking and consistency of products, as well as in baking application (Niba et al., 2001).

There were no significant differences in oil absorption index of composite flours and wheat flour (Fig. 1). Oil absorption index was important since oil acts as flavor retainer and increases the mouth feel of foods, improvement of palatability and extension of shelf life particularly in bakery or meat products where fat absorptions are desired (Aremu et al., 2007).

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The results of the swelling power of composite flours and wheat flour are presented in Fig. 2. The swelling power shows the degree of the water absorption of the starch granules in the flour (Carcea and Acquistucci, 1997). There were significant differences ($P < 0.05$) in swelling power among composite flours and wheat flour. The swelling power of composite flours irrespective of the ratio of sweet potato flour and maize starch. At the same amount of soybean flour in the composite flour, there were no significant differences in swelling power. The increasing of soybean flour amount will decrease the swelling power in composite flour.

There were significant differences ($P < 0.05$) in baking expansion expressed in the specific volume of composite flour and wheat flour (Fig. 3). The composite flours had higher specific volume than those in wheat flour. The higher specific volume in composite flours may be caused by xanthan gum which modified the texture properties of dough and inhibited the retrogradation and syneresis of starch (Seetapan et al., 2013). The higher baking expansion presented a model for dough expansion during oven rise and stages of the bubble growth in viscous fluid. Increasing viscosity and increasing internal bubble pressure gave rise to larger tensile stresses on the cell surface which resulted in cell rupture at the end of oven rise (Vatanasuchart et al., 2005).

3.2. Rheological properties of composite flours

The rheological properties of composite flours were presented in Table 2. There were significant differences ($P < 0.05$) among the composite flours and wheat flour. The pasting temperature is an indication of the minimum temperature required to cook or gelatinize the flour (Kaur and Singh, 2005). There were no significant differences in pasting temperatures between various treatments of composite flours as well as wheat flour, but in general the pasting temperature in composite flours was lower than that of wheat flour. Pasting temperature is the temperature at which the first detectable increase in viscosity is measured and it is an index characterized by the initial change due to the swelling of starch (Eniola and Delarosa, 1981). Pasting temperature has been reported to relate to water availability. Gluten or xanthan gum acts as water-binding agent (Ghiasi et al., 1993). Generally greater water availability is followed by a lower gelatinization temperature (White et al., 1989). It seems that the gluten in wheat flour held more water, so that some of the water is not available for starch which resulted in reduction of gelatinization. Low gelatinization temperature provides greater availability of starch to amylolytic enzymes during baking process which is desirable in bread making.

The results of the rheological characteristics indicate that the higher level of soybean flour reduced the peak viscosity (PV), hot paste viscosity (HPV), break down viscosity (BD), cold paste viscosity (CPV), and setback viscosity (SB) of composite flour. This is due to the existence and interaction of components like fat and protein from soybean flour with sweet potato flour and maize starch that decrease the viscosity (White et al., 1989). In general the viscosity of composite flour was lower than wheat flour. Sweet potato flour has the lower viscosity than wheat flour, but maize starch has a higher viscosity than wheat flour. There was a change in the pasting profile of the composite flour compared with its raw material. The PV of composite flours ranged from 703.67 cP for $T_4$ to 1127.67 cP for $T_1$. It was found that the peak viscosity decreased as soybean flour supplementation increased, but the ratio of sweet potato flour and maize starch only has a little effect on peak viscosity of composite flours. The differences in the starch and protein composition in the flours could affect pasting viscosity and properties (Batey and Curtin, 2000; Morris et al., 1997). The composite flours had lower peak viscosity as opposed to the wheat flour. The peak viscosity attained during the heating portion of tests indicates the water binding capacity of starch mixture. This often correlates with final product qualities. Otegbayo et al. (2006) found that starch from yam (Dioscorea alata) varieties with higher peak...
viscosities produced pounded yam with good textural quality whereas the D. alata varieties, with lower peak viscosities, did not give pounded yam of the acceptable textural quality.

The HPV which is the minimum viscosity value measuring the ability of paste to withstand breakdown during cooling ranged between 598.33 cP for T₁ to 832.00 cP for T₆. Breakdown is a parameter that measures the ease with which the swollen granules can be disintegrated (Kaur and Singh, 2005). The lower breakdown viscosities (BD) were found in composite flours, as compared with the wheat flour. This may be due to restricted swelling of the starch granules, which increased the tendency of the hydrophilic chain of the fiber in composite flours to bind with hydrogen bonds of the water, causing a decrease in available water for starch granules. The breakdown viscosity also decreases as increase in soybean flour level in composite flour. It can be regarded with the susceptibility of protein to heat damage (Devi and Haripriya, 2012). The final viscosity (CPV) indicated the re-association of starch granules especially amylose during cooling time after gelatinization and the formation of gel network (Ortega-Ojeda et al., 2004). The lower breakdown (BD) and final viscosity (CVP) as increase in soybean flour indicate the ability of the flour to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear stress during stirring (Lee et al., 2012).

Setback value has been reported to correlate with ability of starches to gel into semi solid paste. The lower setback viscosity with increase in soybean flour and maize starch level may be due to increased hydrogen bonding during cooling and the high amylose content of maize starch. This leads to the growth of gel micellar regions, and hence increase in index of retrogradation (Hodge and Osman, 1971; Otegbayo et al., 2006) found that pounded yam samples with good textural quality were produced from yam starch with higher setback values.

Stability and setback ratio increased as the level of soybean flour increased. Stability ratio explains the resistance of a starch paste to viscosity breakdown as shear is applied. Composite flours showed significantly (P < 0.05) higher stability ratio (Table 3) than those of wheat flour. The blending of sweet potato flour, maize starch, soybean flour and xanthan gum gave the flours a longer paste peak times, and hence swelled more gradually and not as susceptible to mechanical damage (Wiesenborn et al., 1996). Setback ratio, which is an indication of starch retrogradation tendency after gelatinization, was significantly lower (P < 0.05) in composite flour than those in wheat flour. The value of setback ratio of composite flour was between the value of setback ratio of sweet potato flour and maize starch.

### 3.3. Physical and sensory properties of bread samples

Results of the physical characteristics of composite bread are given in Table 3. There were significant differences in loaf weight among the bread samples (P < 0.05). The weight loaf of composite bread sample increases with increasing of soybean level in the composite flour. The loaf volume of composite bread samples ranged from 264.33 to 278.00 ml, and the specific volume ranged from 1.45 to 1.59 ml/g ml. This result showed that as level of soybean flour increases, the decrease in specific volume was more remarkable. The specific volume, which is the ratio of loaf volume and weight, has been generally adopted in the literature as a more reliable measure of loaf size (Shittu et al., 2007). Loaf volume is affected by the quantity and quality of protein in the flour (Ragae and Abdel-Aal, 2006), whereas loaf weight is basically determined by the quantity of dough baked and the amount of moisture and carbon dioxide diffused out of the loaf during baking. The observed higher in loaf weight of composite bread samples is as a result of less retention of carbon dioxide gas in the blended dough, hence providing

### Table 2: Rheological properties of composite flours (T₁–T₆), wheat flour (WF), sweet potato flour (SPF) and maize starch (MS).

<table>
<thead>
<tr>
<th>Flour</th>
<th>$P_{temp}$ (°C)</th>
<th>PV (Cp)</th>
<th>HPV (Cp)</th>
<th>BD (Cp)</th>
<th>SB (Cp)</th>
<th>CPV (Cp)</th>
<th>SR</th>
<th>SBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1$</td>
<td>70.6b</td>
<td>1127b</td>
<td>832b</td>
<td>295b</td>
<td>477d</td>
<td>1243e</td>
<td>0.74e</td>
<td>1.50f</td>
</tr>
<tr>
<td>$T_2$</td>
<td>73.5b</td>
<td>1079b</td>
<td>804b</td>
<td>275b</td>
<td>508e</td>
<td>1313hc</td>
<td>0.75f</td>
<td>1.63d</td>
</tr>
<tr>
<td>$T_3$</td>
<td>74.8b</td>
<td>1089b</td>
<td>793f</td>
<td>296b</td>
<td>570b</td>
<td>1363hc</td>
<td>0.73f</td>
<td>1.72e</td>
</tr>
<tr>
<td>$T_4$</td>
<td>75.6b</td>
<td>703d</td>
<td>696d</td>
<td>97d</td>
<td>375f</td>
<td>982e</td>
<td>0.86e</td>
<td>1.62d</td>
</tr>
<tr>
<td>$T_5$</td>
<td>75.6b</td>
<td>718ed</td>
<td>594d</td>
<td>120d</td>
<td>422e</td>
<td>1021de</td>
<td>0.83b</td>
<td>1.71e</td>
</tr>
<tr>
<td>$T_6$</td>
<td>75.7b</td>
<td>764c</td>
<td>605d</td>
<td>159f</td>
<td>476d</td>
<td>1081d</td>
<td>0.79f</td>
<td>1.79b</td>
</tr>
<tr>
<td>WF</td>
<td>77.8b</td>
<td>2433a</td>
<td>1281a</td>
<td>1151a</td>
<td>1311a</td>
<td>2594a</td>
<td>0.53f</td>
<td>2.02e</td>
</tr>
<tr>
<td>SPF</td>
<td>67.8b</td>
<td>1831</td>
<td>1002</td>
<td>829</td>
<td>563</td>
<td>1565</td>
<td>0.56</td>
<td>1.53</td>
</tr>
<tr>
<td>MS</td>
<td>74.12</td>
<td>3669</td>
<td>1785</td>
<td>1844</td>
<td>1594</td>
<td>3379</td>
<td>0.49</td>
<td>1.89</td>
</tr>
</tbody>
</table>

$P_{temp}$ = pasting temperature, PV = Peak viscosity, HPV = hot paste viscosity, BD = Breakdown viscosity, B = setback viscosity, CPV = cold paste viscosity, SR = Stability ratio, SBR = setback ratio. The values are expressed as the mean of three replicate samples. Values with similar superscripts in a column do not differ significantly (P < 0.05).

### Table 3: Physical characteristics of bread from composite flours (T₁–T₆) and wheat flour (WF).

<table>
<thead>
<tr>
<th>Samples</th>
<th>Loaf Volume (ml)</th>
<th>Loaf Weight (g)</th>
<th>Loaf Specific Volume (ml/g)</th>
<th>Firmness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1$</td>
<td>278.00b</td>
<td>178.03b</td>
<td>1.59b</td>
<td>3.44b</td>
</tr>
<tr>
<td>$T_2$</td>
<td>273.33b</td>
<td>172.03b</td>
<td>1.59b</td>
<td>3.35b</td>
</tr>
<tr>
<td>$T_3$</td>
<td>273.00b</td>
<td>171.27b</td>
<td>1.59b</td>
<td>3.21b</td>
</tr>
<tr>
<td>$T_4$</td>
<td>264.33b</td>
<td>183.43b</td>
<td>1.45</td>
<td>3.68b</td>
</tr>
<tr>
<td>$T_5$</td>
<td>265.33b</td>
<td>182.10b</td>
<td>1.45</td>
<td>3.44b</td>
</tr>
<tr>
<td>$T_6$</td>
<td>269.33b</td>
<td>181.87b</td>
<td>1.48</td>
<td>3.44b</td>
</tr>
<tr>
<td>WF</td>
<td>673.33b</td>
<td>175.33b</td>
<td>3.64</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Values with similar superscripts in a column do not differ significantly (P < 0.05).
dense bread texture (Rao and Hemamalini, 1991). Gas production in the bread dough with higher level of soybean flour was less impaired than that of doughs with lower level of soybean flour. The reduction of extensibility of dough with increased substitution level of non-wheat flour protein was also reported by Chauhan et al. (1992) and Okaka and Potter (1977). The results show that the highest specific volume of composite bread samples found in bread sample was made from $T_3$ (40% sweet potato starch, 40% maize flour and 19.5% soy bean flour).

The texture analysis showed a significantly higher firmness in bread made from composite flour when compared with bread from wheat flour ($P < 0.05$), as shown in Table 3. The significant negative correlations were found between specific volume and firmness of bread samples ($r = -0.995$, $P < 0.05$). Firmness was also inversely correlated with baking expansion ($r = -0.996$, $P < 0.05$), and positively with water absorption index ($r = 0.879$, $P < 0.05$).

The viscosity of composite flour was lower than wheat flour. The results obtained from this study have demonstrated the potential for the bread production from composite flour. The indicative optimal proportion of composite flour was sweet potato flour 40%, maize starch 40%, soybean flour 19.5% and xanthan gum 0.5%, and at this proportion the bread had the acceptable sensory quality. This work recommends the promotion and utilization of sweet potato flour and maize starch in bread making in Indonesia that is known to fully depend on imported wheat. However further research work should be focused on how to improve the sensory quality and hence acceptability of composite breads.

### Conflict of interest

The authors do not have conflict of interest.

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Sweet potato, maize, and soybean composite flour


