Journal of the Saudi Society of Agricultural Sciences (2015) **xxx**, xxx–xxx

King Saud University
Journal of the Saudi Society of Agricultural Sciences
www.ksu.edu.sa
www.sciencedirect.com

FULL LENGTH ARTICLE

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

Elisa Julianti *, Herla Rusmarilin, Ridwansyah, Era Yusraini

Department of Food Science Technology, Faculty of Agriculture, University of Sumatera Utara, Jalan Prof. A. Sofyan No. 3, Medan, Indonesia

Received 12 March 2015; revised 17 May 2015; accepted 26 May 2015

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.

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

* Corresponding author.
E-mail address: elizayulianti@yahoo.com (E. Julianti).
Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2015.05.005
1658-077X

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 (Ihekoronye 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 Papageorgiou, 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 *Xanthmonas campestris* (Achayuthakan and Suphantharika, 2008). It is commonly used with emulsifier 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 Tbk. 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 1 Different treatment used to prepare composite flour.

Treatment	Sweet potato flour (%)	Maize starch (%)	Soybean flour (%)
T_1	60	20	19.5
T_2	50	30	19.5
T_3	40	40	19.5
T_4	50	20	29.5
T_5	40	30	29.5
T_6	30	40	29.5

Please cite this article in press as: Julianti, E. et al., Functional and rheological properties of composite flour from sweet potato, maize, soybean and xanthan gum. Journal of the Saudi Society of Agricultural Sciences (2015), http://dx.doi.org/10.1016/j.jssas.2015.05.005

(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:

$$LSV = \text{loaf volume(ml)}/\text{loaf weight(g)} = \text{ml/g}$$

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).

Please cite this article in press as: Julianti, E. et al., Functional and rheological properties of composite flour from sweet potato, maize, soybean and xanthan gum. Journal of the Saudi Society of Agricultural Sciences (2015), http://dx.doi.org/10.1016/j.jssas.2015.05.005

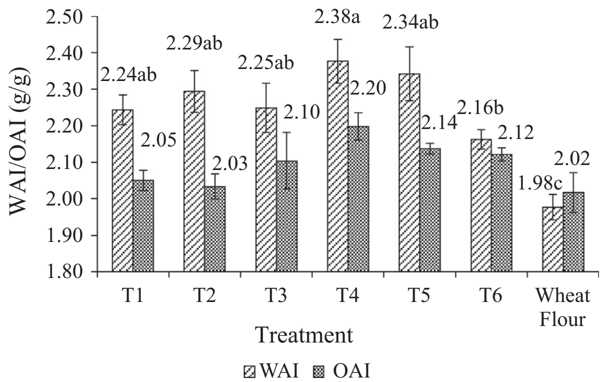

Figure 1 Water and oil absorption index of composite flours made from different blends (T_1–T_6) and wheat flour (T_7).

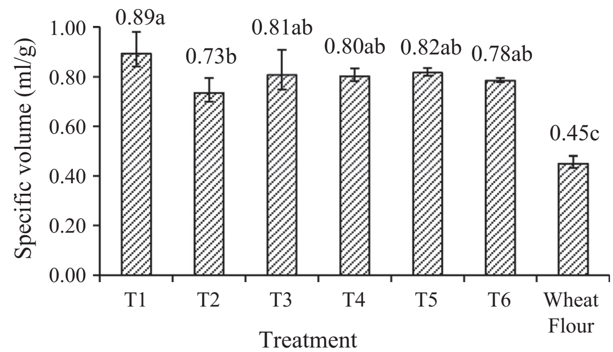

Figure 3 The specific volume of composite flours made from different blends (T_1–T_6) and wheat flour (WF).

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 binding capacity. 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.

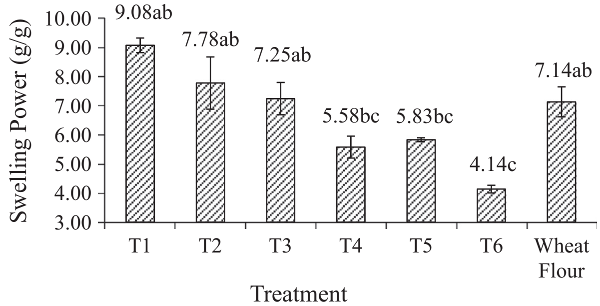

Figure 2 The swelling power of composite flours made from different blends (T_1–T_6) and wheat flour (WF).

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 (Dautant et al., 2007). 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

Table 2 Rheological properties of composite flours (T_1–T_6), wheat flour (WF), sweet potato flour (SPF) and maize starch (MS).

Flour	P_{temp} (°C)	PV (Cp)	HPV (Cp)	BD (Cp)	SB (Cp)	CPV (Cp)	SR	SBR
T_1	70.6^{b}	1127^{b}	832^{b}	295^{b}	477^{d}	1243^{c}	0.74^{de}	1.50^{e}
T_2	73.5^{b}	1079^{b}	804^{b}	275^{b}	508^{c}	1313^{bc}	0.75^{d}	1.63^{d}
T_3	74.8^{b}	1089^{b}	793^{c}	296^{b}	570^{b}	1363^{b}	0.73^{e}	1.72^{c}
T_4	75.6^{b}	703^{d}	696^{d}	97^{d}	375^{f}	982^{e}	0.86^{a}	1.62^{d}
T_5	75.6^{b}	718^{cd}	598^{d}	120^{d}	422^{e}	1021de	0.83^{b}	1.71^{c}
T_6	75.7^{b}	764^{c}	605^{d}	159^{c}	476^{d}	1081^{d}	0.79^{c}	1.79^{b}
WF	77.8^{a}	2433^{a}	1281^{a}	1151^{a}	1311^{a}	2594^{a}	0.53^{f}	2.02^{a}
SPF	67.78	1831	1002	829	563	1565	0.56	1.53
MS	74.12	3669	1785	1884	1594	3379	0.49	1.89

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 ($P < 0.05$).

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 T_5 to 832.00 cP for T_1. 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 (CPV) 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, 1971Otegbayo 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 (Ragaee 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 3 Physical characteristics of bread from composite flours (T_1–T_6) and wheat flour (WF).

Samples	Loaf Volume (ml)	Loaf Weight (g)	Loaf Specific Volume (ml/g)	Firmness (N)
T_1	278.00^{b}	178.03^{b}	1.59^{b}	3.44^{ab}
T_2	273.33^{b}	172.03^{c}	1.59^{b}	3.35^{ab}
T_3	273.00^{b}	171.27^{c}	1.59^{b}	3.21^{b}
T_4	264.33^{b}	183.43^{a}	1.45^{c}	3.68^{a}
T_5	265.33^{b}	182.10^{a}	1.45^{c}	3.44^{ab}
T_6	269.33^{b}	181.87^{a}	1.48^{c}	3.44^{ab}
WF	673.33^{a}	175.33^{bc}	3.64^{a}	0.76^{c}

Values with similar superscripts in a column do not differ significantly ($P < 0.05$).

Please cite this article in press as: Julianti, E. et al., Functional and rheological properties of composite flour from sweet potato, maize, soybean and xanthan gum. Journal of the Saudi Society of Agricultural Sciences (2015), http://dx.doi.org/10.1016/j.jssas.2015.05.005

Table 4 Sensory evaluation of bread from composite flours (T_1–T_6) and wheat flour (WF).

Samples	Texture	Aroma	Color	Taste
T_1	3.87^{b}	3.92^{ab}	3.98^{bc}	3.96^{ab}
T_2	3.88^{b}	3.73^{b}	3.88^{c}	4.06^{ab}
T_3	4.00^{b}	4.01^{ab}	4.09^{b}	4.11^{ab}
T_4	3.98^{b}	2.71^{c}	4.08^{b}	3.75^{b}
T_5	2.59^{c}	2.68^{c}	2.59^{d}	3.01^{c}
T_6	2.47^{c}	2.61^{c}	2.50^{d}	2.96^{c}
WF	4.69^{a}	4.42^{a}	4.68^{a}	4.30^{a}

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 ($r = 0.879$, $P < 0.05$).

Sensory evaluation of composite bread samples as compared to the control (100% wheat flour) was given in Table 4. There were no significant differences ($P > 0.05$) with respect to bread texture, aroma, color and taste in composite bread samples with the same level in soybean flour. However, as the level of soybean flour incorporation increased there was a significant change in the sensory attributes of bread samples. The sensory evaluation showed that the bread produced from composite flours, was significantly different ($P > 0.05$) than bread from 100% wheat flour, in terms of texture and color. But, there were no significant difference ($P > 0.05$) in taste and aroma of bread from composite flour with 19.5% of soybean flour (T_1, T_2, and T_3) and bread from 100% of wheat flour (WF). It evident from the results that bread prepared from 100% wheat flour had highest sensory score followed by bread prepared from T_4 composite flour (40% SPF, 40% MS, 19.5% SF and 0.5% XG).

4. Conclusion

The functional and rheological properties of the composite flours were determined by the proportion of each constituent flour. Blending of sweet potato flour, maize starch, soybean flour and xanthan gum had a dramatic influence on all the rheological properties. The higher level of soybean flour significantly reduced the peak viscosity, hot paste viscosity, break down viscosity and cold paste viscosity of composite flour. 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.

Acknowledgment

We wish to thank to Directorate General of Higher Education, Ministry of National Education Republic of Indonesia for funding this research through "Hibah Strategis Nasional 2013" project.

References

AACC, 2000. Approved Methods of the American Association of Cereal Chemists, 10th Ed. Methods 54-21 and 10-10B. AACC International, St. Paul, M.N.

Achayuthakan, P., Suphantharika, M., 2008. Pasting and rheological properties of waxy corn starch as aff ected by guar gum and xanthan gum. Carbohyd. Polym. 71, 9–17.

Adeyemi, S.A.O., Ogazi, P.O., 1985. The place of plantain in composite flour. Commerce Industry, Lagos state, Nigeria, WHO Rep Seri 1973 No 522 WHO Geneva.

Akubor, P.I., Ukwuru, M.U., 2005. Functional properties and biscuit making potential of soybean and cassava flour blends. Plant Food Hum. Nutr. 58, 1–12.

Alvarenga, N.B., Lidon, F.C., Belga, E., Motrena, P., Guerreiro, S., Carvalho, M.J., Canada, J., 2011. Characterization of gluten-free bread prepared from maize, rice and tapioca flours using hydrocolloid seawed agar–agar. Rec. Res. Sci. Tech. 3 (8), 64–68.

Ansari, A., Kalbasi-Ashtari, A., Gerami, A., 2013. Effects of defatted soy flour, xanthan gum, and processing temperature on quality criteria of spaghetti. J. Agr. Sci. Tech. 15, 265–278.

Aremu, M.O., Olaofe, O., Akintayo, E.T., 2007. Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelation properties. J. Food Technol. 5 (2), 109–115.

Arendt, E.K., Moorisey, A., Moore, M.M., Dal Bello, F., 2008. In: Arendt, E.K., Dal Bello, F. (Eds.), Gluten-Free Cereal Products and Beverages. Academic Press, London.

Arocas, A., Sanz, T., Fiszman, S.M., 2009. Improving effect of xanthan and locust bean gums on the freeze-thaw stability of white sauces made with different native starches. Food Hydrocolloid. 23, 2478–2484.

Basman, A., Koksel, H., Ng, P.K.W., 2003. Utilization of transglutaminase use to increase the level of barley and soy flour incorporation in wheat flour breads. J. Food Sci. 68 (8), 2453–2460.

Batey, I.L., Curtin, B.M., 2000. The effects on the pasting viscosity of starch and flour of different operating conditions for the Rapid Visco Analyzer. Cereal Chem. 77, 754–760.

Carcea, M., Acquistucci, R., 1997. Isolation and functional characterization of Fonio (*Digitaria exillis* Stapf.) starch. Starch/Stärke 49, 131–135.

Chauhan, G.S., Zillman, R.R., Eskin, N.A.M., 1992. Dough mixing and breadmaking properties of quinoa-wheat flour blends. Int. J. Food. Sci. Tech. 27, 701–705.
Dautant, F.J., Simancas, K., Sandoval, A.J., Muller, A.J., 2007. Effect of temperature, moisture, and lipid content on rheological properties of rice flour. J. Food Eng. 78, 1159–1166.
Demiate, I.M., Dupuy, N., Huvenne, J.P., Cereda, M.P., Wosiacki, G., 2000. Relationship between baking behavior of modified cassava starches and starch chemical structure determined by FTIR spectroscopy. Carbohyd. Polym. 42, 149–158.
Devi, K., Haripriya, S., 2012. Pasting behaviors of starch and protein in soy flour-enriched composite flours on quality of biscuits. J. Food Process. Pres. 38 (1), 116–124.
Dhingra, S., Jood, S., 2001. Organoleptic and nutritional evaluation of wheat breads supplemented with soybean and barley flour. Food Chem. 77, 479–488.
Doxastakis, G., Papageorgiou, M., 2007. Technological properties and nonenzymatic browning of white lupin protein enriched spaghetti. J. Food Chem. 101, 57–64.
Eggum, B.O., Beame, R.M., 1983. The Nutritive Value of Seed Proteins. In: Gottschalk, W., Muller, H.P. (Eds.), Seed Protein Biochemistry, Genetics and Nutritive Value. Martinus Nijhoff/DR W.Kunk Publishers, London.
Eniola, L., Delarosa, L.C., 1981. Physicochemical characterizes of yam starches. J. Food Biochem. 5, 115–130.
FAOSTAT, 2004. Agricultural data (last updated August 27,2004). Rome, Italy: Food and Agriculture Organization of the United Nations. <http://faostat.fao.org/site/408/Desktop Default.aspx?PageID =408>. [accessed 05.10.14].
Gallagher, E., Kunkel, A., Gormley, T.R., Arendt, E.K., 2003. The effect of dairy and rice powder addition on loaf and crumb characteristics, and on shelf life (intermediate and long-term) of gluten-free breads stored in a modified atmosphere. Eur. Food Res. Technol. 218, 44–48.
Ghiasi, K., Hoseney, R.C., Varriano-Marston, E., 1993. Effects of flour components and dough ingredients on starch gelanitization. Cereal Chem. 60 (1), 58–61.
Gomez, M., Ronda, F., Caballero, A.C., Blanco, A., Rosell, C.M., 2007. Functionality of different hydrocolloids on the quality and shelf life of yellow layer cakes. Food Hydrocolloid. 21, 167–173.
Guarda, A., Rosell, C.M., Benedito, C., Galotto, M.J., 2004. Diff erent hydrocolloids as bread improvers and antistaling agents. Food Hydrocolloid. 18, 241–247.
Hodge, J.E., Osman, E.M., 1971. Carbohydrates. In: Fenema, O.R. (Ed.), Principle of Food Science (Part I Food Chemistry). Mercel Dekker Publishers, New York, pp. 41–138.
Hugo, L.F., Rooney, L.W., Taylor, J.R.N., 2000. Malted sorghum as a functional ingredient in composite bread. Cereal Sci. 79 (4), 428–443.
Ihekoronye, A.J., Ngoddy, P.O., 1985. Integrated Food Science and Technology for the Tropics. Macmillan Publs, Ltd.
[ILSI] International. Life Sciences Institute, 2008. Nutritionally improved sweet potato. Washington, D.C.: IntI. Life Sciences Inst. (<http://www3.interscience.wiley.com/cgi-bin/fulltext/119423793/PDFSTART>). [accessed 5.10.14].
Kaur, M., Singh, N., 2005. Studies on functional thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars. Food Chem. 91, 403–411.
Lazaridou, A., Duta, D., Papageorgiou, M., Belc, N., Biliaderis, C.G., 2007. Effects of hydrocilloids on dough rheology and bread quality parameters in gluten-free formulation. J. Food Eng. 79, 1033–1047.
Leach, H.W., McCowan, L.D., Schoch, T.J., 1957. Structure of the starch granule: swelling power and solubility patterns of different starches. Cereal Chem. 36, 534–544.
Lee, J.H., Cho, A.R., Hong, J.Y., Park, D.-J., Lim, S.-T., 2012. Physical properties of wheat flour composites dry-coated with microparticulated soybean hulls and rice flour and their use for low-fat doughnut preparation. J. Cereal Sci. 63, 636–643.
Livingstone, A.S., Feng, J.J., Malleshi, N.G., 1993. Development and nutritional quality evaluation of weaning foods based on malted, popped and dried wheat and chickpea. Int. J. Food Sci. Tech. 28, 35–43.
Makri, E.A., Doxastakis, G.I., 2006. Study of emulsions stabilized with *Phaseolus vulgaris* or *Phaseolus coccineus* with the addition of Arabic gum, locust bean gum and xanthan gum. Food Hydrocolloid. 20, 114–1152.
Moore, M.M., Heinbockel, M., Dockery, P., Ulmer, H.M., Arendt, E.K., 2006. Network formation in gluten-free bread with application of transglutaminase. Cereal Chem. 83 (1), 28–36.
Morris, C., King, G.E., Rubenthaler, G.L., 1997. Contribution of wheat flour fraction to peak hot paste viscosity. Cereal Chem. 74, 147–153.
Niba, L.L., Bokonga, M.M., Jackson, E.L., Schlimme, D.S., Li, B.W., 2001. Physicochemical properties and starch granular characteristics of flour from various *Manihot esculenta* (cassava) genotypes. J. Food Sci. 67 (5), 1701–1705.
Okaka, J.C., Potter, N.N., 1977. Functional and storage properties of cowpea powder – wheat flour blends in breadmaking. J. Food Sci. 42 (3), 828–833.
Oladunmoye, O.O., Akinoso, R., Olapade, A.A., 2010. Evaluation of some physical-chemical properties of wheat, cassava, maize and cowpea flours for bread making. J. Food Qual. 33, 693–708.
Ortega-Ojeda, F.E., Larsson, H., Eliasson, A.-C., 2004. Gel formation in mixtures of high amylopectin potato starch and potato starch. Carbohyd. Polym. 56, 505–514.
Otegbayo, B., Aina, J., Asiedu, R., Bokanga, M., 2006. Pasting characteristics of fresh yams (*Dioscorea* spp.) as indicators of textural quality in a major food products-'pounded yam'. Food Chem. 99, 663–669.
Ragaee, S., Abdel-Aal, E.S.M., 2006. Pasting properties of starch and protein in selected cereals and quality of their products. Food Chem. 95, 9–18.
Rao, H.P., Hemamalini, R., 1991. Effect of incorporating wheat bran on rheological characteristics and bread making quality of flour. J. Food Sci. Tech. 28, 92–97.
Ribotta, P.D., Ausar, S.F., Morcillo, M.H., Perez, G.T., Beltramo, D.M., Leon, A.E., 2004. Production of gluten-free bread using soybean flour. J. Sci. Food Agr. 84, 1960–1974.
Sanchez, H.D., Osella, C.A., Torre, M.A., 2004. Use of response surface methodology to optimize gluten-free bread fortified with soy flour and dry milk. Food Sci. Technol. Int. 10, 5–9.
Seetapan, N., Fuongfuchat, A., Gamonpilas, C., Methacanon, P., Pongjaruwat, W., Limparyoon, N., 2013. Effect of modified tapioca starch and xanthan gum on low temperature texture stability and dough viscoelasticity of a starch-based food gel. J. Food Eng. 119, 446–453.
Shittu, T.A., Raji, A.O., Sanni, A.O., 2007. Effect of baking time on some physical properties of bread loaf. Food Res Int. 40 (2), 280–290.
Shrestha, A.K., Noomhorm, A., 2002. Comparison of physicochemical properties of biscuits supplemented with soy and kinema flours. Int. J. Food Sci. Tech. 37, 361–368.
Vatanasuchart, N., Naivikul, O., Charoenrein, S., Sriroth, K., 2005. Molecular properties of cassava starch modified with different UV irradiation to enhance baking expansion. Carbohyd. Polym. 61, 80–87.
White, R.J., Abbas, I.R., Johnson, L.A., 1989. Freeze-thaw stability and refrigerated storage retrogradation of starches. Starch/Stärke 41, 176–180.
Wiesenborn, D., Lorenzen, J., Berglund, P., 1996. Suitability of edible bean and potato starches for starch noodles. Cereal Chem. 73, 302–303.
Woolfe, J., 1992. Sweetpotato: An Untapped Food Resource. Cambridge University Press, pp. 1–13; 366–372.

Please cite this article in press as: Julianti, E. et al., Functional and rheological properties of composite flour from sweet potato, maize, soybean and xanthan gum. Journal of the Saudi Society of Agricultural Sciences (2015), http://dx.doi.org/10.1016/j.jssas.2015.05.005