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Physicochemical properties of fermented sweet potato flour in wheat composite flour and its use in white bread

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Abstract

Sweet potatoes were peeled, washed, sliced and fermented for 7 days by spontaneous, pickled brine and *Lactobacillus plantarum* FNCC 0123, dried and milled into flours. These fermented flours and the composite flours consisting of 60% wheat flour and 40% fermented sweet potato flour were analyzed for the physicochemical and pasting properties. Non-fermented sweet potato flour and its composite with wheat flour were also prepared as controls. The composite flours were used as raw material for white bread making and were tested for sensory properties and bread loaf specific volume. The results showed that the physicochemical and pasting properties of sweet potatoes flours were affected by fermentation. In general the fermented sweet potato flours (both composite and non-composite) had a lower pH, and solubility, but had higher amylose content, swelling power, water absorption capacity, and whiteness than those of controls. Fermentation increased peak viscosity, break down, and set back value, but deacreased the temperature of maximum viscosity of all sweet potatoes flours. The sensory analysis indicated that the bread from wheat-pickle brine composite flour was the best treatment with the characteristics of brightest crust color, softest crumb, more uniform pores, and highest bread loaf specific volume.

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Introduction

Increasing demand for wheat flour as the main ingredient in most carbohydrate-food has led to various problems, primarily, on economic sectors because wheat could not be cultivated well in Indonesia. The national consumption of wheat in Indonesia is reported in the amount of 18 kg/capital/year, and this increases about 5-10% every year (Food Review Indonesia, 2011). The largest portion of wheat flour uses is for noodle, while the rest is used for cake, breads, snacks, biscuits, and fried foods. The demand for bread, especially white bread has increased significantly and the growth of bakery bussines has reached 7-10% every year. To address the needs for wheat, substitution of wheat with other local flour is needed. Fermented sweet potato and wheat composite flours could be used as an alternative.

Sweet potato (SP) is widely grown, however, in its nature, sweet potatoes processed into flour has some drawback properties such as slighly dark color (Trejo-González *et al*., 2014),and low loaf volume (Amal, 2015) when applied on bread products. In this study, lactic acid fermentation could be aimed to improve SP flour properties. Some studies on the effects of lactic acid spontaneous fermentation on the physicochemical properties of starches suggested that fermentation may change the amorphous region of the starch granule as well as the chemical components thereby modify the physicochemical properties of the starches and the flour (Numfor *et al*.,1995; Putri *et al*., 2011; Putri *et al*., 2012; Deng *et al*., 2013). Furthermore, on the bread dough application, lactic acid bacteria fermentation increases the loaf volume (Corsetti *et al*., 1998), improves texture changes (Clarke *et al*., 2002), contributes directly to bread flavour, especially, through the synthesis of acetic acid (Gobbetti *et al*., 2005; Ur-Rehman *et al*., 2006).

The effect of fermentation on the physicochemical characteristics of sweet potatoes flour has been studied (Chinsamran *et al*., 2005; Oluwole *et al*., 2012; Amajor *et al*., 2014; Yuliana *et al*., 2014). However, little work has been done on how fermentation affects the physical and pasting properties of composite SP flour or how it changes the properties of bread. In this study, lactic acid fermentation of sweet potatoes was performed through various methods such as spontaneously, addition of pure culture, and SP pickle brine starter. This fermentation is expected to improve the physicochemical properties of the flour which could be used as a wheat flour substitute in bread making.

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Materials and Methods

Materials

The materials used in this experiment, local sweet potatoes Ciceh variety, harvested 100 days after planting, were purchased from a farm at Metro, Lampung. *Lactobacillus plantarum* FNCC 0123 was purchased from The Inter University Centre for Food and Nutrition, University of Gajah Mada. *Lactobacillus plantarum* starter culture was prepared by inoculating 1 mL of pure culture in 9 mL MRS Broth media and incubated at a temperature of 37°C for 48 hours. The amount of the cells in this preparation was approximately 10^7 CFU/mL. A pickle brine starter was prepared by fermenting diced sweet potato in sterilized bottles containing 3% saline and 1% (w/w) sucrose solution for 7 days at 37°C (Yuliana and Nurdjanah, 2009).

Fermentation process and manufacturing of sweet potato flour

The sweet potatoes were divided into 4 representative lots. Each lot was prepared by weighing a total of 1.5 kg sweet potatoes, peeled, washed thoroughly in tap water, sliced using a Hobart slicer with 1 mm thickness and dispersed in a 5 L closed plastic container. A 4 L sterile saline solution containing 3% sodium chloride and 1% sucrose was added to the container. The 3 lots were inoculated at the rate of 10% based on the volume of fermentation solution with Lactobacillus plantarum starter culture, and SP pickle brine, while one lot was spontaneously fermented (no starter added). One lot of the sample without fermentation was served as a control. The fermentation processes were carried out at 30±2°C for 7 days in an anaerobic condition.

After the fermentation processes were completed, the sweet potato slices were washed, drained and dried in an oven (Memmert, UM 200, Laboratory oven 0-200°C) at a temperature of 60°C for 10-12 hours until the moisture content reached 6-10%. The dried fermented sweet potato were powdered into flour using a Hammer Mill (FCT Z500, Ramesia) and sieved using a 80 mesh siever. Part of this fermented sweet potatoes flour (SPF) was blended with wheat flour at 40% inclusion for both fermented and non fermented flour to form composite flours. The fermented SPF and its composite flour were packed in sealed polyethylene bags for further analysis.

Preparation of bread from composite flours

The manufacture of bread was performed using the procedure of two-steps dough method (Hardoko *et al*., 2010) with slight modifications. The first step was the preparation of initial dough by mixing 200 g of wheat flour, 5 g instant yeast, 100 mL of water to form firm dough. This initial dough was fermented for one hour at 30°C. In the second step, dry ingredients consisting of 200 g SPF, 300 g wheat flour, 5 g instant yeast, 5 g bread improver, 5 g baking powder, 70 g milk powder, 50 g sugar, 200 mL water were mixed to form a half-proofed dough. Both this dough and the initial dough were mixed together with shortening (50 g) and salt (2 g) to form a uniform and firm dough, shaped as a round dough, rested for 10 minutes at 30°C, cut, sheeted and re-rested for 10 minutes. The dough was then put in the proofer for one hour at 30°C and finally baked in an oven at 170°C for 35 minutes.

Chemical analysis and whiteness of composite flour

The chemical compositions were analyzed using methods described in AOAC (2005) with the number of method description as follows: crude fiber (Method No. 920.86), protein (Method No 920.87), ash (Method 923.03), moisture (Method 925.10), lipid (Method No 923.05), and starch (Method No 945.37). The pH was measured in triplicate using a pH meter (Jenway 3330, UK). SPF whiteness was determined using a Powder Whiteness Tester (Model C 100, Kett Electric Laboratory, Italia).

Swelling power and solubility

Swelling power and solubility was determined using the modified method of Deng *et al*. (2013). Each flour sample (0.1 g) was dispersed in 12.5 mL of distilled water in a centrifuge tube, heated in a water bath for 30 min at 60, 70, 80 and 90°C, and centrifuged (Beckman GP, UK) at 3000 rpm for 15 min. The supernatants were collected and dried at 105°C to constant weight. The solubility was calculated as a percentage of the weight of the dried supernatant compared to the weight of the dried flour (0.1 g). The precipitates were obtained and weighed directly to determine the swelling power.

Water absorption capacity (WAC)

Water absorption capacity of the flours were determined using the method modified of Adebowale and Maliki (2011). Five gram of each sample was weighed into a centrifuged tube, and 30 mL of distilled water was added and vigorously mixed. The samples were allowed to stand for 30 min and centrifuged (Beckman GP, UK) at 3000 rpm for 15 min. The top clean layer was decanted off and the sample reweighed. The amount of water in the sample was recorded as weight gain (g/g) and was taken as water absorbed.

Determination of pasting properties

The pasting properties of the SPF and composite flour samples were determined using Brabender Micro Viscoamylograph (Brabender OHG, Duisburg, Germany). Thirty grams (dry basis) of flour samples was suspended in 470 mL of distilled water to obtain 6% suspension w/w. The suspension was transferred into the bowl of Brabender, heated from 35 to 95°C at a rate of 1.5°C/min and kept for 20 min at 95°C. It was cooled to 50°C at a rate of 1.5°C/min and held at 50°C for 20 min. Parameters measured were beginning temperature of gelatinization, peak viscosity, temperature at maximum viscosity, breakdown and setback viscosities.

Amylose content

The amylose content was determined using amylose-iodine complex procedure as described by Yuan *et al.* (2007). The absorbance of samples and amylose standard were read at 620 nm using a spectrophotometer (Shimadzu UV-1700, Tokyo). The plot of samples absorbance against pure potato amylose standard curve was used to calculate the amylose content of the samples.

Bread quality analysis

The sensory evaluation was carried out 24 hours after preparation of the bread samples. The sensory panel consisted of 20 semi-trained students of Agro-industrial Product Technology, University of Lampung. The Hedonic test with 7-point scale ranging from 1 (extremely dislike) to 7 (like extremely) described by Macfie *et al.*(1989) was used in the sensory evaluation of bread preference. The bread samples were evaluated for taste, crust color, crumb color, crumb texture, porosity, and overall acceptability.

Statistical analysis

Experiments were performed in three replications with a randomized complete block design. The data of physicochemical and bread quality were subjected to one-way ANOVA test and Duncan Multiple Range Test (DMRT) to compare among treatments at the 5% significant level. Whereas the data of proximate composition and pasting properties were reported as mean of duplicate determination.

Results and Discussion

Proximate composition of SPF and fermented SPF-wheat composite flour

The proximate composition of SPF was presented in Table 1. Generally, fermentation seemed to decrease protein, starch, lipid, crude fiber and ash content, but increase moisture content. However, the effect of the fermentation method was not consistent for the ash and crude fiber content. This pattern of the proximate content was also found in wheat-fermented sweet potato composite flours.

The decrease in protein, lipid, and starch contents observed in fermented flours was partly due to the activity of lactic acid bacteria during fermentation. Lactic acid bacteria were reported to produce various depolymerized enzymes that could hydrolize protein, starch, and lipid (Meyers *et al.*, 1996; Law and Haandrikman, 1997; Petrova *et al.*, 2012). Because of the activities of these enzymes, the protein, starch, and lipid content of fermented flour decreased, except for lipid content of *Lactobacillus plantarum* fermented flour. Some researchers reported that some bacteria might produce lipid during their metabolism process (Patnayak and Sree, 2005; Meng *et al.*, 2009 and Lemmer *et al.*, 2015) thereby contributing to lipid content. In the composite flour, the increase in protein content was originated from wheat protein, where the average protein of wheat flour added was 11.29%. The ash content decreased slightly in fermented flour samples except for *Lactobacillus plantarum* SPF where the ash content was almost similar to that of non-fermented flour. This was partly due to the use of some minerals by lactic acid bacteria as coenzymes during fermentation or due to possible leaching of soluble mineral into fermenting medium. The amount of losses was fermentation type-dependent. The moisture content of fermented SPF was higher compared to that of non-fermented sweet potato flour. The increase in the moisture contents of fermented flour could be due to water absorption during soaking at the fermentation process.

Physicochemical properties of SPF and fermented SPF-wheat composite flour

Physicochemical properties of SPF and its composite were presented in Table 2. The pH values of fermented SPF were lower compared to those of non-fermented and composite flours. This was due to the contribution of organic acids produced by LAB (lactic acid bacteria) that dominate microorganisms during sweet potato fermentation. The increase in LAB activity could cause the increase in total acid produced and consequently lowered the pH value. This was in agreement with previous reports on fermented sweet potato (Yuliana and Nurdjanah, 2009; Oluwole *et al.*, 2012; Yuliana *et al.*, 2014), and cassava (Kakou *et al.*, 2010; Tetchi *et al.*, 2016). According to Salminen and Wright (1993), LAB are acid tolerant bacteria and produce lactic acid as a

Table 1. Proximate composition of wheat, fermented sweet potato flours and its composite flour

Flour	Moisture (%)	Protein (%)	Lipid (%)	Crude Fiber (%)	Ash (%)	Starch (%)
Wheat	5.52 ±0.11	11.29 ±0.71	1.38 ±0.01	0.62 ±0.03	0.38 ±0.06	59.06 ±0.29
C-SPF	6.76 ± 0.06	5.95 ± 0.80	1.17 ± 0.10	6.75 ± 0.18	2.83 ± 0.70	68.73 ± 0.18
S-SPF	7.62 ± 0.30	3.29 ± 0.11	0.71 ± 0.03	6.12 ± 0.17	1.98 ± 0.51	62.92 ± 0.17
PB-SPF	9.93 ±0.38	2.20 ±0.22	0.92 ±0.06	8.27 ±0.12	2.07 ±0.02	57.15 ±0.16
Lp- SPF	7.84 ± 0.06	2.70 ± 0.05	1.21 ± 0.06	5.68 ± 0.46	3.42 ± 0.26	58.26 ± 0.17
CC-SPF	7.45 ± 1.67	6.78 ± 0.14	0.97 ± 0.12	3.02 ± 0.07	1.40 ± 0.09	62.93 ±0.07
CS- SPF	8.59 ± 2.70	8.16 ± 3.00	1.05 ± 0.08	3.77 ± 0.18	1.89 ± 0.01	60.61 ±0.14
CPB- SPF	9.04 ±2.18	8.10 ±3.02	1.09 ±0.12	5.09 ±1.60	0.85 ±0.25	58.30 ±0.25
C*Lp*-SPF	7.78 ± 1.55	7.79 ± 2.31	1.24 ± 0.08	2.94 ± 0.29	1.38 ± 0.12	58.74 ±0.07

Data are mean values of duplicate determination ± standard deviation

C-SPF = control sweet potato flour, S-SPF=Spontaneous sweet potato flour, PB-SPF =Pickle brine sweet potato flour, Lp-SPF= *Lactobacillus plantarum* sweet potato flour , CC-SPF=Composite control sweet potato flour , CS-SPF = Composite Spontaneous sweet potato flour, CPB-SPF =Composite Pickle brine sweet potato flour, CLp-SPF = Composite *Lactobacillus plantarum* sweet potato flour

Table 2. Physico chemical (pH, WAC, Amylose, Whiteness) of Fermented sweet potatoes flour and its composite Flour

Treatments	pH	WAC (%)	Amylose (%)	Whiteness (%)
C-SPF	6.23±0.035[f]	222.86±4.86[c]	22.46±0.63[a]	69.8 ± 1.73[a]
S-SPF	4.11±0.036[b]	203.42±16.40[c]	27.68±0.44[c]	75.43±1.15[b]
PB-SPF	4.14±0.017[b]	211.54±23.92[c]	28.44±0.89[c]	83.03±0.76[f]
Lp-SPF	3.70±0.001[a]	256.94±22.45[d]	27.22±1.78[bc]	77.00±1.35[cd]
CC-SPF	6.18±0.001[f]	132.42±5.26[a]	25.25±2.67[bc]	74.95 ± 0.09[b]
CS-SPF	5.15±0.035[d]	135.49±9.06[a]	24.78±1.14[b]	78.56± 1.27[de]
CPB-SPF	5.38±0.12[e]	114.72±2.95[a]	26.44 ±0.24[bc]	80.28±0.20[e]
C*Lp*-SPF	4.22±0.075[c]	167.03±9.41[b]	28.46±0.73[c]	76.27± 1.32[bc]

Data are mean values of triplicate determination ±standard deviation. Means within a column with different letters are significantly ($p<0.05$) different.

C-SPF = control sweet potato flour, S-SPF=Spontaneous sweet potato flour, PB-SPF =Pickle brine sweet potato flour, Lp-SPF= *Lactobacillus plantarum* sweet potato flour , CC-SPF=Composite control sweet potato flour , CS-SPF = Composite Spontaneous sweet potato flour, CPB-SPF =Composite Pickle brine sweet potato flour, CLp-SPF = Composite *Lactobacillus plantarum* sweet potato flour

major end product of sugar fermentation.

The lowest pH (3.7) was found in *Lactobacillus plantarum* – fermented flour. The nature of *Lactobacillus plantarum* has a role in the decrease of pH value due to its high amilolytic activity and strong acid producing LAB (Sharpe, 1979; Salminen and Wright, 1993). The composite flours, however, had higher pH content because of the addition of 60% wheat flour which has pH of 6.05, and this contributed to the increase in the final pH.

In term of water absorption capacity (WAC), there was no significant ($p<0.05$) difference between spontaneous SPF and non-fermented SPF. However, the WAC was slightly increased in *Lactobacillus plantarum* SPF,whereas WAC in spontaneous SPF was similar to that of non-fermented SPF. This could be due to the fact that fermentation may have caused loosening chain in the starch granules. The water could easily bind in the looser area in amylose and amylopectin (Singh *et al.*,2004)

Amylose content determined by amylose-iodine complex procedure exceeded 22 % in both fermented and its composite flour. The amylose content of non-fermented SPF was significantly ($p<0.05$) lower compared to those of fermented SPF. This indicated that the amorphous region of amylopectin might have been hydrolyzed to short chain amylose during fermentation and counted as amylose-like material. According to Banks *et al.* (1974), a polysaccharide of 18 glucose units was the minimum necessary for the formation of iodine complex. In this study, therefore, it is possible that there was intensification of the blue color by short chain amylose resulting from enzyme hydrolysis of amylopectin during fermentation. However, this phenomenon was not observed in those of non-fermented SPF. In addition,

Table 3. Swelling power (SWP) and solubility (SL) of flour at 60-90°C

	Temperature							
	60°C		70°C		80°C		90°C	
Treatments	SWP (%)	SL (%)	SWP (%)	SL (%)	SWP (%)	SL (%)	SWP (%)	SL (%)
C-SPF	3.37±0.01^{e}	16.1±0.17^{f}	3.62± .17^{a}	9.66±1.58^{b}	6.36±0.17^{e}	8.30±0.47^{b}	7.16±0.01^{d}	8.81±0.11^{g}
S-SPF	2.68±0.00^{a}	4.87±0.15^{b}	5.63±0.23^{ef}	2.49±0.16^{a}	6.02±0.43^{de}	2.13±0.47^{a}	6.31±0.00^{b}	4.80±0.00^{d}
PB-SPF	2.74±0.01^{b}	4.03±0.04^{a}	5.80±0.18^{f}	2.19±0.15^{a}	5.78±0.28^{cd}	1.52±0.32^{a}	8.29±0.01^{f}	2.55±0.01^{a}
Lp-SPF	2.73±0.00^{b}	6.90±0.13^{d}	6.27±0.09^{g}	3.44±0.73^{a}	6.10±0.19^{e}	2.94±0.62^{a}	10.17±0.00^{h}	8.67±0.00^{f}
CC-SPF	3.64±0.01^{g}	20.8±0.17^{g}	4.18± .07^{b}	7.29±0.44^{b}	4.86±0.35^{ab}	6.42±0.75^{b}	6.86±0.00^{c}	7.77±0.00^{e}
CS-SPF	2.91±0.01^{c}	5.25±0.08^{c}	4.79±0.35^{c}	2.95±0.24^{a}	4.94±0.49^{ab}	2.90±0.29^{a}	8.70±0.00^{g}	2.50±0.01^{a}
CPB-SPF	3.48±0.01^{f}	9.25±0.00^{e}	4.87±0.21^{d}	2.91±0.22^{a}	4.73±0.36^{a}	2.69±0.24^{a}	8.28±0.00^{d}	3.88±0.05^{c}
CLp-SPF	3.09±0.01^{d}	5.10±0.06^{c}	5.25±0.28^{e}	2.87±0.32^{a}	5.30±0.48b^{c}	2.09±0.38^{a}	7.64±0.01^{e}	3.49±0.06^{b}

Data are mean values of triplicate determination ±standard deviation. Means within a column with different letters are significantly ($p<0.05$) different.

C-SPF = control sweet potato flour, S-SPF=Spontaneous sweet potato flour, PB-SPF =Pickle brine sweet potato flour, Lp-SPF= *Lactobacillus plantarum* sweet potato flour , CC-SPF=Composite control sweet potato flour , CS-SPF = Composite Spontaneous sweet potato flour, CPB-SPF =Composite Pickle brine sweet potato flour, CLp-SPF = Composite *Lactobacillus plantarum* sweet potato flour

during drying in an oven, there could be amylose degradation mainly in the amorphous region due to sweet potato β amylase activity. This activity may probably not have occurred in those fermented SPF because β amylase inactivation during fermentation processes as the pH drop around 3 to 4. Tavano *et al.* (2013) reported that sweet potato β amylase has an optimal activity at pH around 6, at temperature between 50 and 80°C, and this enzyme is inactive at low pH.

As for the whiteness, the fermented SPF had higher whiteness compare to that of non-fermented SPF. The fermentation improved the whiteness of fermented SPF. This can be ascribed to flour purification by spontaneous, pickle brine and *Lactobacillus plantarum* fermentation process. During fermentation, there was a decrease in ash, and protein content (Table 1), as well as sugar content. These constituents are among factors affecting the whiteness of flours. Similar findings were reported for rice flour (Lu *et al.*, 2005), and fufu cassava (Sobowale *et al.*, 2007). During fermentation, bacteria would produce proteinase which degraded protein in sweet potatoes, convert free sugar to lactic acid thus the content of protein and free sugar in fermented flour was lower than those in non fermented SPF. A higher protein and free sugar content in control flour may cause non-enzymatic browning during flour drying which result in darker color, thus reducing whiteness of flour.

Fermentation caused significant changes in swelling power of SP flour, as shown in Table 3. At 60ºC the swelling power of SP flour and its fermented SPF as well as that of wheat-fermented SP composite flour was low, and this value increased when the heating was done at 70, 80 and 90ºC. A significant change in swelling power was observed in SP flour and increase in its value was observed when heating of temperature increased from 70 to 90ºC. According to Jacguier *et al.* (2006), the starch granules start to swell rapidly only after the temperature reached the onset of the gelatinization temperature. The beginning of gelatinization temperature as determined by micro visco amylograph for non fermented sweet potatoes flour was 74.40ºC, for fermented sweet potatoes flour (74.13-74.14°C) (Table [illegible] and for wheat flour 80°C (data not shown). This corresponded to the start of the rapid increase of swelling power of these flours. Similar observation was reported in previous study on spontaneously fermented sweet potato flour (Yuliana *et al.,* 2014).

Solubility of SPF at different temperatures was shown in Table 3. Fermentation caused significant ($p<0.05$) decrease in solubility of fermented flour. Changes in solubility of SPF were observed at different temperatures (60 to 90ºC), and this was possibly due to some degree of degradation of starch granules occurred during the fermentation process.

Pasting properties

Table 4 shows the pasting properties for non-fermented SPF, fermented SPF and their composite with wheat flour. It was noticed that fermentation significantly ($p<0.05$) increased the peak viscosity, break down and set back value. Meanwhile, the temperature of viscosity maximum decreased. This pattern was also observed in the composite wheat-fermented SPF. However, the pasting viscosity

Table 4. Pasting properties of fermented sweet potatoes flour and its composite flour

Treatments	Beginning of gelatinization (°C)	Maximum viscosity (BU)	Temp. at max viscosity (°C)	Breakdown (BU)	Setback (BU)
C-SPF	74.4±0.34	222.8±0.42	88±1.12	42.5±1.41	57.4±1.27
S-SPF	74.13±0.11	749.5±2.83	88.1±0.57	274±22.63	139.50±7.78
PB-SPF	73.4±0.000	919.3±6.72	85.28±0.32	363.5±7.07	167.4±3.18
Lp-SPF	74.15±0.21	805.25±13.08	83.58±0.04	400.75±7.42	125.5±9.19
CC-SPF	73.475±0.81	233.75±7.42	92.6±0.21	64.75±1.77	148±13.42
CS-SPF	74.55±0.07	447 ±7.77	90.78±0.04	86.5±0.71	260.5±9.19
CPB-SPF	74.33±0.39	469±4.24	90.6±0.14	85.25±5.30	245.5±3.54
CLp-SPF	74.25±0.14	512.25±0.35	89.73±0.46	125.5±2.82	179±10.61

Data are mean values of duplicate determination ± standard deviation.

C-SPF = control sweet potato flour, S-SPF=Spontaneous sweet potato flour, PB-SPF =Pickle brine sweet potato flour, Lp-SPF= *Lactobacillus plantarum* sweet potato flour , CC-SPF=Composite control sweet potato flour , CS-SPF = Composite Spontaneous sweet potato flour, CPB-SPF =Composite Pickle brine sweet potato flour, CLp-SPF = Composite *Lactobacillus plantarum* sweet potato flour

Table 5. Sensory and specific volume of plain bread made from composite wheat-fermented SPF

Parameter	Composite-Control	Composite-Spontaneus	Composite-Pickle brain	Composite-*L.plantarum*
Crust color	3.53 ± 0.18^{a}	4.71 ± 0.54^{b}	5.65±0.18^{b}	5.00 ± 0.68^{b}
Crust hardness	3.99 ± 0.79^{a}	4.47 ± 0.46^{ab}	5.06±0.15^{b}	4.34 ± 0.53^{ab}
Crumb texture	3.80 ± 0.59^{a}	4.29 ± 0.72^{ab}	4.95±0.35^{b}	3.56 ± 0.58^{a}
Porosity	4.00 ± 0.38^{ab}	4.10 ± 0.46^{ab}	4.71±0.42^{b}	3.72 ± 0.53^{a}
Acid aroma	4.81 ± 0.70^{a}	4.62 ± 0.42^{a}	4.68±0.52^{a}	4.00 ± 1.18^{b}
Overall acceptance	4.03 ± 0.52^{a}	4.54 ± 0.51^{ab}	5.41±0.51^{b}	3.77 ± 0.67^{a}
Specific volume	3.26 ± 0.18^{b}	3.25 ± 0.13^{ab}	3.52±0.08^{c}	3.07 ± 0.19^{a}

Data are mean values of triplicate determination ±standard deviation. Means within a row with different letters are significantly ($p<0.05$) different.

Score of crust color: from 7 for pale brown to 3 for brown, and 1 for dark brown. Score of crust hardness and crumb texture: from 7 for very soft to 1 for very hard; Score of porosity: from 7 for very uniform to 1 for extremely not uniform; Score of acid aroma: from 1 for very acidic to 7 for extremely not acidic; Overall acceptance: from1 for extremely dislike to 7 for extremely like).

values (peak, break down and set back viscosities) of all non composite flours were lower.

Significant increase of the breakdown value for fermented SPF has implication in reducing the ability of starch granules to be less resistant to degradation during heating and shearing. This could be explained by the fact that fermentation had caused degradation of some starch granules and consequently the flours become less resistant to deformation and have lower paste stability during heating. Among the fermented SPF, *Lactobacillus plantarum* had the lowest stability that might be due to its severe starch broken granule. Another important finding was retrogradation phenomena which also significantly increased in the final product after cooling as indicated with high setback viscosity value. The setback viscosity is a measure of recrystallization of gelatinized starch during cooling (Lee *et al.*, 1995) and is usually used to predict the retrogradation tendency of starch (Karim *et al*., 2000).

White plain bread quality

Table 5 shows that white plain bread made from 40% of composite fermented SPF except for *Lactobacillus plantarum* treatment gained higher specific volume and sensory scores in comparison to control. This findings support previous research, where the addition of fermented flour to whole dough improved the overall quality of its bread as shown in wheat-barley-oat composite bread (Rieder *et al*., 2012), in steamed wheat-rice composite bread (Ilowefah *et al.,* 2014). Dough acidification is an important issue since it affects bread volume, crumb softness and retrogradation phenomena. The reduction in the pH during dough fermentation activates some enzymes such as α-amylase and protease. The acid condition due to the addition of fermented flour to wheat dough could cause the gluten network to be more extensible and softer, leads to higher retention of CO_2 produced during dough fermentation; consequently increase the loaf volume (Clarke *et al.*, 2002). It is also reported that adding pre-fermented bran with yeast and lactic acid bacteria improved the CO_2 retention during dough proofing, and as a result increased the bread volume and crumb softness (Salmenkallio-Marttila *et al.*, 2001; Katina *et al.*, 2005).

However, among the fermented composite breads, *Lactobacillus plantarum* treatment had the lowest bread specific volume (Table 5). This might be attributed to its highest acidity (Table 2). According to Gocmen *et al*. (2007), high rate of acidity might increase hydrolysis of the protein network, resulted less elastic and softer dough that led in a reduction in the bread volume and elevated staling rate and bread firmness.

The color of all fermented composite bread crust was described as pale brown by panelist and these were different from composite control bread which had brown color. This was correlated with the whiteness of the flour used as raw material for bread production. The whiteness of control SPF (69.8±1.73%) was lower than that of fermented SPF (75.43±1.15 to 83.03±0.76%) as shown in Table 2. Based on all properties, bread from composite flour consisting pickle brine-fermented sweet potato and wheat had the best overall acceptance as indicated by its score of 5.4.

Conclusion

It was concluded that fermentation had significant effects on the physicochemical properties of wheat-fermented sweet potato composite flours, thus it affected the bread quality as well. Based on the sensory analysis, the bread from composite wheat-pickle brine fermented sweet potato flour was the best bread as it had brightest crust color, softest crumb, more uniform pores, and highest bread loaf specific volume.

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