

FUNCTIONAL AND THERMAL PROPERTIES OF FLOUR OBTAINED FROM SUBMERGED FERMENTATION OF DURIAN (*DURIO ZIBETHINUS* MURR.) SEED CHIPS USING *LACTOBACILLUS PLANTARUM*

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ABSTRACT

Durian (*Durio zibethinus* Murr.) is one of the most popular seasonal fruits in South East Asia, mainly Thailand, Indonesia, Malaysia and the Philippines. After consuming of the fruit pulp, the abundant durian seeds are usually disposed. However, they can be eaten after being boiled, roasted, baked, fried or cooked. Unfortunately, there is no sufficient information on the innovative utilizations of the durian seeds as raw materials in the preparation of modern foods. This study aims to characterize the functional and thermal properties of native and fermented durian seed flour obtained from submerged fermentation of durian seed chips using *Lactobacillus plantarum*, so that this information can be used as the basis in the development of functional foods. The effect of solid consistency (5 – 25% w/v), inoculum size (2.5 – 15% w/v) and time (0 – 40 h) on the swelling power, water solubility, water absorption capacity, oil absorption capacity, carbonyl and carboxyl content, degree of substitution and gelatinization temperature of the flour were investigated. Fermentation was found to alter all of the functional and thermal properties of durian seed flour. Although fermentation increased the gelatinization temperature and oil absorption capacity of durian seed flour, their value were still lower than that of wheat flour. Based on the carboxyl group content and degree of substitution, the fermented durian seed flour obtained from fermentation of durian seed chips at 15% w/v solid consistency and 5% v/v inoculums size for 24 h is safe for consumption. Fermented durian seed flour exhibits similar functional properties to that of wheat flour and offers its superiority and high potential applications in the food industry over wheat flour due to its high fiber content ($8.50 \pm 0.26\%$), but low fat content ($0.63 \pm 0.03\%$). However, rigorous research should be conducted to ensure the acceptability and practical implementation of fermented durian seed flour as raw material for the manufacture of bread, cookies, cake and noodle.

Keywords: *Lactobacillus plantarum*; durian seed flour; functional property; thermal property; fermentation

INTRODUCTION

Wheat flour is the main raw material for the manufacture of noodle and baked products, such as breads, cakes, biscuits, and cookies. This is because wheat flour contains gluten, a specific protein that gives a unique nature and functional properties of wheat flour (Tharise et al., 2014). Unfortunately, the climate differences with its origin hardly hinder the mass cultivation of wheat in the tropical countries, such as Indonesia and Malaysia (Amin et al., 2007). In fact, Indonesia had to import 11.48 million ton of wheat flour or equivalent to US \$ 2.65 billion in 2017 to supply the domestic demand, including the need in diversification of food products (Bizteka, 2018). Because some individuals with celiac disease may often experience undesirable reactions to gluten, many attempts have been devoted to develop gluten free food products. Larrosa et al. (2013) proposed the reduction of gluten from food

products through substitution of wheat flour with other food materials having similar physicochemical properties to gluten.

Durian (*Durio zibethinus* Murr.) is one of the most favorite seasonal fruits in South East Asia, especially Thailand, Indonesia, Malaysia and the Philippines (Azima et al., 2017). Statistics Indonesia (2014) reported that Indonesian durian production in 2013 was approximately 1,818,949 tons and was estimated to increase every year. Durian fruit pulp has a unique flavor and strong aroma, which can be consumed fresh or processed into ice cream, pancake and different kind of traditional food products. The edible part of durian fruit is only about 30 – 35% of its total weight, whereas the seeds (20 – 25%) and the shell are usually discarded. It is estimated that the durian seed as by-product of durian fruit production can reach 454,737 tons per year, but its potential has not been extensively utilized. Ripe

durian seeds may comprise up to 51.1% moisture, 43.6% carbohydrates, dietary fiber, polysaccharide gum (20 – 25% w/w), and protein (3 – 5% w/w) (Brown, 1997). Durian seeds can be consumed after being boiled, roasted, fried, baked or cooked (Berg, 1979). Durian seed also contains heteropolysaccharide-protein polymer composed of galactose and glucose as major monosaccharide, which is believed to have similar roles to gluten in the food preparation (Amid and Mirhosseini, 2011). Amin and Arshad (2009) reported that the whole and dehulled durian seed flour contains approximately 73.90% and 76.8% of carbohydrate. They also found that based on its pasting properties, durian seed flour may withstand tough cooking condition. In addition, it has also been used as a source of dietary fiber, as dough and as a thickening agent in the food manufacturing (Amid and Mirhosseini, 2011). Hence, durian seed flour exhibits a promising potential to substitute the use of wheat flour in various food applications.

Lactobacillus is the most common strain in a class of lactic acid bacteria (LAB), which perform an essential role in the preservation and production of healthy foods. Lactic acid fermentation using a variety of strains of LAB is the oldest conventional method for preparation of fermented vegetables, meat products, dairy products and cereal foods (Romanová and Urminská, 2017). During the fermentation processes, LAB generates particular metabolites such as enzymes, acids, alcohols, antibiotics, carbohydrates, and inhibitory compounds that are responsible to the safety, sensory and nutritional quality of fermented foods. Since chemical modifications of cereal, tuber and seed flours are being avoided due to the presence of undesirable residues in the products, lactic acid fermentation is likely to be the better option to modify the functional properties of durian seed flour.

The aim of the current study was to investigate the effect of solid consistency (5– 25% w/v), inoculum size (2.5 – 15% v/v), and fermentation time (0 – 40 h) on the swelling power, water solubility, carbonyl and carboxyl group content, water absorption capacity, oil absorption capacity, degree of substitution and gelatinization temperature during fermentation of durian seed chips using *Lactobacillus plantarum*.

Scientific hypothesis

During fermentation *Lactobacillus plantarum* may produce specific metabolites that contribute to the safety, sensory, nutritional and functional properties of fermented foods. Fermentation of durian seed chips using *Lactobacillus plantarum* is expected to alter the proximate composition, functional and thermal properties of the flour obtained. This information will be beneficial in broadening the potential applications of durian seed flour within the food industries, especially cake, biscuits, cookies and noodles.

MATERIAL AND METHODOLOGY

Plant material, microorganism and chemicals

The durian (*Durio zibethinus* Murr.) seeds used in this study were obtained from durian sellers in Gunungpati, Semarang, Indonesia. They were cleaned from the remaining fruit pulp and washed carefully with flowing water. To prevent sprouting, the seeds were dried in a

convective drying oven at ambient temperature (30 °C). The air dried seeds were collected and packed in plastic bags and kept in a dry and cool place at 5 °C for 24 h as recommended earlier (Larrosa et al., 2013). *Lactobacillus plantarum* sp CCRC 12251 was obtained Food and Nutrition Inter-University Center, Universitas Gadjah Mada, Yogyakarta-Indonesia and maintained in Mann Rogassa Sharpe (MRS) agar slant at 4 °C. All of the chemicals and reagents used for analyses were the products of Sigma-Aldrich with analytical grade (purity \geq 98% w/w) and were purchased from an authorized chemicals distributor in Semarang.

Inoculum preparation

The inoculum was made in a 250 mL Erlenmeyer flask containing 100 mL of modified MRS liquid medium (peptone, 10; beef extract 10; yeast extract 5; glucose 20; Na₂HPO₄; sodium acetate 5; triammonium citrate 2; MgSO₄ 0.2; MnSO₄ 0.2; and CaCO₃ 4 g.L⁻¹, Tween 80 0.1 mL, and pH 6.8) by transferring a loop full of microorganisms (*Lactobacillus plantarum*) from a stock culture and incubated at 35 °C and 120 rpm for 48 h in an orbital incubator-cum-shaker. The number of viable bacteria was quantified by the total plate count (TPC) method as suggested by previous researchers (Rizzello et al., 2010). The inoculums were found to contain 3×10^7 CFU.mL⁻¹.

Durian seed chips fermentation

Durian seeds were sliced to obtain chips with \pm 5 mm thickness. They were then introduced into 200 mL distilled water in 500 mL Erlenmeyer flasks to obtain various solid consistencies (5 – 25% w/v). The durian seed chips were inoculated with various sizes (2.5 – 15% v/v) of freshly prepared inoculums and covered with aluminum foil. To avoid starch gelatinization, no thermal sterilization was performed. The fermentation flasks were mounted on a horizontal shaker waterbath to control the temperature (35 °C) and to provide sufficient mixing. Fermented durian chip samples were withdrawn from the fermentation system at 8, 16, 24, 32 and 40 h. After being thoroughly washed with flowing water, the fermented durian seed chips were overlaid as a single layer on drying pans and were dehydrated in an electric oven at 40 °C for 3 days. Then, the dried chips were subjected to size reduction using a locally fabricated crusher before milling them in a ball mill to obtain fine flour. The flour was then sieved through -180 μ m +250 μ m screens from which only flour particles retained on the 250 μ m were used in this study. The flour was stockpiled in zip-lock polyethylene plastic bags and deposited in covered plastic containers at 20 °C for further uses and analyses as recommended earlier by Retnowati et al. (2018).

Raw material and product analysis

Chemical properties

The proximate composition of all flour samples was analyzed following the official method of analysis (Latimer, 2016). The carboxyl content of the flour was

Table 1 Effect of fermentation time on functional and thermal properties of fermented durian seed flours.

Functional properties	Fermentation time (h)						Korean wheat flour (KWF)
	0 (native)	8	16	24	32	40	
WS (%)	7.42 ±0.18	8.60 ±1.08	8.35 ±1.56	7.84 ±0.33	6.79 ±1.05	5.97 ±1.61	7.86 ±0.42
SP (g.g ⁻¹)	8.03 ±0.13	11.33 ±0.20	10.80 ±0.08	8.50 ±0.26	7.11 ±0.40	6.26 ±0.20	8.50 ±0.50
WAC (g.g ⁻¹)	1.51 ±0.20	2.13 ±0.02	2.04 ±0.04	1.62 ±0.08	1.52 ±0.21	1.42 ±0.26	1.50 ±0.05
OAC (g.g ⁻¹)	0.24 ±0.03	0.31 ±0.08	0.29 ±0.05	0.29 ±0.06	0.27 ±0.01	0.25 ±0.07	0.81 ±0.04
Carbonyl (%)	0.27 ±0.06	0.35 ±0.08	0.40 ±0.04	0.48 ±0.05	0.33 ±0.05	0.30 ±0.03	n.a.
Carboxyl (%)	0.12 ±0.08	0.28 ±0.01	0.38 ±0.04	1.03 ±0.11	0.62 ±0.18	0.56 ±0.10	n.a.
DS	n.a.	0.03 ±0.02	0.04 ±0.00	0.08 ±0.02	0.05 ±0.01	0.02 ±0.01	n.a.
T _o (°C)	51.69 ±0.85	n.a.	n.a.	56.59 ±1.21	n.a.	n.a.	57.80 ±1.50
T _p (°C)	56.91 ±1.20	n.a.	n.a.	59.35 ±1.13	n.a.	n.a.	63.90 ±1.10
T _c (°C)	63.37 ±1.30	n.a.	n.a.	66.24 ±1.05	n.a.	n.a.	70.30 ±1.50

Note: n.a.: data not available. KWF: korean wheat flour (Chung et al., 2010).

determined as previously described (Chattopadhyay et al., 1997), while the carbonyl content was measured according to the titrimetric hydroxylamine method (Smith, 1967). The degree of substitution (DS) of the fermented durian seed flour was determined titrimetrically, following the method of Sodhi and Singh (2005).

Swelling power and water solubility

The swelling power (SP) and water solubility (WS) of durian seed flour were determined by the method of Afoakwa et al. (2012). Swelling power is measured as the weight (g) of the swollen sediment per g of dry flour, whereas water solubility is reported as the percentage (by weight) of the flour sample that is dissolved molecularly upon heating in water at 60 °C.

Water/oil absorption capacity

Water and oil absorption capacities (WAC/OAC) for each durian seed flour sample were measured by the method of Abbey and Ibeh (1988). The sample (10% w/v) was carefully weighed into a clean conical flask and was mixed rigorously with distilled water/oil using a warring mixer for 30 s. The sample was then let to stand for 30 min at ambient temperature, after which it was centrifuged at 5000 rpm for 30 min. The free water or oil (supernatant) was read directly from the graduated centrifuge cuvette. The absorbed water/oil was converted to weight (in grams) by multiplying by the respective density (water, 1 g. mL⁻¹ and soybean oil, 0.924 g.mL⁻¹). The water and oil absorption capacities were reported in grams of water/oil absorbed per gram of durian seed flour sample.

Thermal properties

The thermal analysis of durian seed flour was carried out by differential scanning calorimetry (DSC) using a Seiko differential scanning calorimeter (DSC 210) (Seiko Instruments Inc., Chiba, Japan) supported with a thermal analysis data station and data recording software. Before being subjected to DSC analysis, the durian seed flour of 20% water content was prepared by addition of 11 µL deionized water using a microsyringe to 3 mg flour sample (dry basis) in the DSC pans, which were then sealed, reweighed and let to stand overnight at ambient temperature

before analysis to achieve sample and water equilibrium. The analysis used scanning temperatures range of 25 – 300 °C and heating rate of 10 °C.min⁻¹ as previously described by Retnowati et al. (2018). The measurements were performed under a dynamic nitrogen atmosphere (30 mL.min⁻¹) in punctured aluminum pans to avoid condensation. In all measurements, the thermogram was recorded with an empty aluminum pan as a reference.

Statistical analyses

All measurements were performed in triplicates and the data obtained were reported as mean ±Standard deviation. Significant differences between the mean values at significance level *p* <0.05 were compared using Student's test facility available in MS Excel version 2010.

RESULTS AND DISCUSSION

Effect of fermentation time

This investigation was performed by fermentation of durian seed chips using solid consistency of 15% w/v and inoculums size of 5% v/v from 0 – 40 h at ambient temperature. The results are presented in Table 1. The swelling power, water solubility and oil absorption capacity of native durian seed flour were lower than those of Korean wheat flour. Surprisingly, the water absorption capacity of native durian seed flour was comparable to that of Korean wheat flour (Chung et al., 2010). During fermentation, the swelling power, water solubility, water absorption capacity, oil absorption capacity and carbonyl content of durian seed flour increased with time to a maximum value and leveled off. However, the time to reach the maximum value of those parameters was different one to the others. In addition, the oil absorption capacity of fermented durian seed flour remained far below the oil absorption capacity of Korean wheat flour.

Table 1 shows that the swelling power, water solubility and water absorption capacity of the fermented durian seed flour were close to those of Korean wheat flour when fermentation was carried out for 24 h. According to the European Union Scientific Committee for Food (EU SCF), the safe level of carboxyl group in food material is a maximum of 1.1% (Commission of the European

Table 2 Effect of solid consistency on functional and thermal properties of fermented durian seed flours.

Functional properties	Solid consistency (% w/v)						Korean wheat flour (KWF)
	0 (native)	5	10	15	20	25	
WS (%)	7.42 ±0.18	6.95 ±0.04	8.35 ±1.56	7.84 ±0.33	7.68 ±0.36	8.00 ±0.13	7.86 ±0.42
SP (g.g ⁻¹)	8.03 ±0.13	8.05 ±0.13	10.80 ±0.08	8.50 ±0.26	7.74 ±0.08	7.50 ±0.37	8.50 ±0.50
WAC (g.g ⁻¹)	1.51 ±0.20	1.52 ±0.02	2.04 ±0.04	1.62 ±0.08	1.64 ±0.03	1.65 ±0.03	1.50 ±0.05
OAC (g.g ⁻¹)	0.24 ±0.03	0.25 ±0.06	0.28 ±0.05	0.29 ±0.06	0.29 ±0.02	0.29 ±0.02	0.81 ±0.04
Carbonyl (%)	0.27 ±0.06	0.20 ±0.02	0.25 ±0.04	0.48 ±0.05	0.31 ±0.05	0.23 ±0.02	n.a.
Carboxyl (%)	0.12 ±0.08	0.63 ±0.04	0.78 ±0.04	1.03 ±0.11	0.83 ±0.08	0.81 ±0.11	n.a.
DS	n.a.	0.09 ±0.02	0.04 ±0.00	0.08 ±0.02	0.04 ±0.00	0.04 ±0.01	n.a.
T _o (°C)	51.69 ±0.85	n.a.	n.a.	56.59 ±1.21	n.a.	n.a.	57.80 ±1.50
T _p (°C)	56.91 ±1.20	n.a.	n.a.	59.35 ±1.13	n.a.	n.a.	63.90 ±1.10
T _c (°C)	63.37 ±1.30	n.a.	n.a.	66.24 ±1.05	n.a.	n.a.	70.30 ±1.50

Note: n.a.: data not available. KWF: korean wheat flour (Chung et al., 2010).

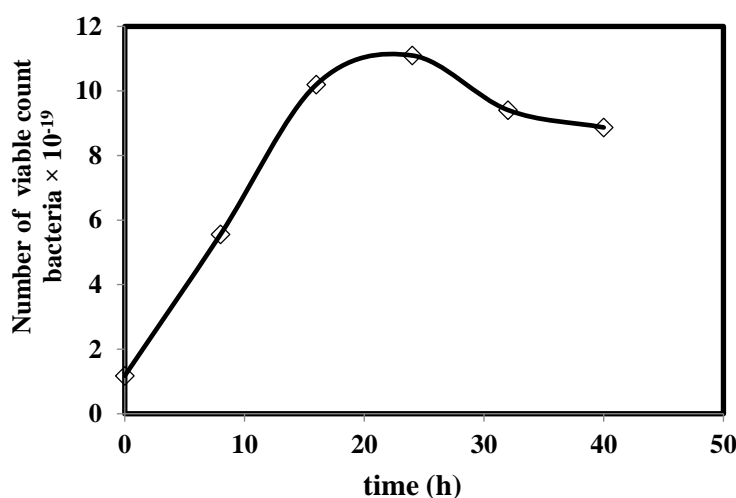


Figure 1 Profile of *Lactobacillus plantarum* growth in durian seed flour media.

Communities, 1976). In addition, the allowable degree of substitution of a specific functional group in the modified flour for food application is between 0.01 – 0.2 (de Graaf et al., 1998). Therefore, 24 h is selected as the best fermentation time for fermentation using *Lactobacillus plantarum*. This phenomenon is confirmed by the growth profile of *Lactobacillus plantarum* in durian seed chips media shown in Figure 1. As seen in Figure 1, the viable count of *Lactobacillus plantarum* reached a maximum value at 24 h fermentation. Similar observation was reported by Passos et al. (1994) on the fermentation of cucumber juice using *Lactobacillus plantarum*. Gupta et al. (2010) also observed a maximum value of viable count of *Lactobacillus plantarum* at the end of 16 – 24 h of fermentation of edible two Irish brown seaweeds. The production level of degrading enzymes used for flour granules modification is the highest during the exponential phase of LAB growth (Chookietwattana, 2014), which exists in the first 10 h of fermentation (Passos et al., 1994).

The thermal property of durian seed flour as reflected by the onset (T_o), peak (T_p) and conclusion gelatinization temperatures (T_c) was lower than that of korean wheat flour (Chung et al., 2010). As expected, fermentation of durian seed chips for 24 h slightly increased the onset, peak and

conclusion gelatinization temperatures of durian seed flour to a closer value to gelatinization temperature of Korean wheat flour. Alonso-Gomez et al. (2016) also found an increase in the gelatinization temperature of cassava starch during fermentation for production of sour starch. The increase in the onset and peak gelatinization temperatures is due to the acidic condition caused by lactic acid as a main product of fermentation, which alter the starch composition and morphology. Fermentation process may also cause dramatic changes of the macromolecular structure and/or conformation of amylose and amylopectin of the starch in the flour granules, which lead to change the gelatinization temperature (Metres et al., 1997).

Effect of solid consistency

This study was conducted by fermentation of durian seed chips at various solid consistencies (5 – 25% w/v) using inoculums size of 5% v/v for 24 h. The results are presented in Table 2.

Table 2 shows that the water solubility and carbonyl content of the fermented flour obtained from fermentation using 5% w/v solid consistency were lower than the native durian seed flour. Similar to the other functional properties, the water solubility and carbonyl content of the fermented

Table 3 Effect of inoculum size on functional and thermal properties of fermented durian seed flours.

Functional properties	Inoculum size (% v/v)					Korean wheat flour (KWF)
	0 (native)	2.5	5	10	15	
WS (%)	7.42 ±0.18	6.58 ±0.20	7.84 ±0.33	7.63 ±0.23	7.55 ±0.04	7.86 ±0.42
SP (g.g ⁻¹)	8.03 ±0.13	8.20 ±0.23	8.50 ±0.26	8.40 ±0.20	8.54 ±0.07	8.50 ±0.50
WAC (g.g ⁻¹)	1.51 ±0.20	1.56 ±0.10	1.62 ±0.08	1.66 ±0.02	1.69 ±0.17	1.50 ±0.05
OAC (g.g ⁻¹)	0.24 ±0.03	0.26 ±0.02	0.29 ±0.06	0.29 ±0.03	0.29 ±0.02	0.81 ±0.04
Carbonyl (%)	0.27 ±0.06	0.12 ±0.07	0.48 ±0.05	0.16 ±0.13	0.11 ±0.03	n.a.
Carboxyl (%)	0.12 ±0.08	0.31 ±0.15	1.03 ±0.11	0.95 ±0.11	0.86 ±0.12	n.a.
DS	n.a.	0.05 ±0.02	0.08 ±0.02	0.10 ±0.01	0.01 ±0.01	n.a.
T _o (°C)	51.69 ±0.85	n.a.	56.59 ±1.21	n.a.	n.a.	57.80 ±1.50
T _p (°C)	56.91 ±1.20	n.a.	59.35 ±1.13	n.a.	n.a.	63.90 ±1.10
T _c (°C)	63.37 ±1.30	n.a.	66.24 ±1.05	n.a.	n.a.	70.30 ±1.50

Note: n.a.: data not available. KWF: korean wheat flour (Chung et al., 2010).

flour increased gradually with solid consistency and achieved a maximum value and then leveled off. When solid consistencies were higher than 10% w/v, no clear effect of solid consistency on oil absorption capacity was observed. Unfortunately, all values of the oil absorption capacity of the fermented durian seed flour were still far lower than that of wheat flour. As expected, the water solubility, water absorption capacity and carboxyl group content of the fermented durian seed flours were higher than those of the native one. These phenomena were likely due to the effect of fermentation and acidification. A similar result was reported by Putri et al. (2011) during their study on the fermentation of cassava starch. However, the carboxyl group content decreased when the solid consistency was increased further, which was due to inhibitions caused by the high substrate concentration. The other reason of decreasing the utilization of starch beyond 15% w/v consistency might be due to the increase in osmotic effects or due to hydrolysis of starch to reducing sugars or the microorganisms were incapable to hydrolyze the starch present in durian seed chips at high consistency because they generally grow and being productive at higher water activity (Ray et al., 2009).

Based on the functional properties value compared to those of wheat flour, food regulations, economical and technological applications, the solid consistency of 15% w/v was chosen as the best fermentation condition. The thermal property of durian seed flour obtained from this condition has been discussed in the previous section.

Effect of inoculums size

This investigation was carried out by fermentation of durian seed chips at various inoculum sizes (2.5 – 15% v/v) using solid consistency of 15% w/v for 24 h. In industrial practices, the microbe loading range for lactic acid fermentation is usually between 3 – 10% of the fermentation broth volume (Clark and Blanch, 1991). A proper microbe loading would reduce the probable existence of lag phase or shorten the lag phase period. The results are reported in Table 3.

In their study on the lactic acid production from paneer whey by *Lactobacillus delbrueckii* in a submerged fermentation process, Tripathi et al. (2015) reported that the lactic acid production increased substantially from 2.8

to 5.6 g.L⁻¹, when the inoculum size was increased from 3 to 8% v/v. However, no significant effect on lactic acid production was noticed when the inoculum size was further increased beyond 8% v/v. A long lag phase is not preferred in the fermentation process because it is time-wasting and the medium is consumed to maintain a viable culture prior to the growth. Therefore, 5% v/v inoculum size performed better than 10% v/v because the lag phase of 5% v/v inoculum size was a little shorter than that of 10% v/v during fermentation of whey using *Lactobacillus bulgaricus* for lactic acid production (Taleghani et al., 2016). In submerged liquid fermentation, an appropriate inoculum size is an absolutely important factor for obtaining high product yield and productivities. At low value of inoculum size, the substrate is slowly utilized by microorganisms and prolongs the incubation time. On the other hand, a large value of inoculum size will lead to competition of growth of microorganisms over the limited substrate supply.

Based on the functional properties value compared to those of wheat flour, food regulations, economical and technological applications, the inoculums size of 5% v/v was selected as the best fermentation condition. The thermal property of durian seed flour obtained from this condition has been discussed in the earlier section.

Proximate composition of durian seed flour

The proximate composition was determined for native and durian seed flour obtained from fermentation of durian seed chips at 15% w/v solid consistency, 5% v/v inoculums size for 24 h. The results are compared with proximate composition of whole durian seed flour (WDSF) and wheat flour reported in the literature by Amin and Arshad (2009) and Chung et al. (2010) presented in Table 4. In general, the proximate composition of native durian seed flour used in this study is comparable to the whole durian seed flour (WDSF) reported by Amin and Arshad (2009).

The moisture contents of durian seed flour obtained from drying in an electric oven at 40 °C for 3 days were lower than 10%. Foods with moisture content higher than 14% are vulnerable to bacterial attacks and mould growth, which produce undesirable changes (Ihekoronye and Ngoddy, 1985). Therefore, the moisture contents of durian seed flours obtained in this study were within the acceptable

Table 4 Proximate composition of native and fermented durian seed flours in comparison to wheat flour

Flour samples	Content (%)					
	Moisture	Protein	Fat	Fiber	Ash	Carbohydrate
NDSF	9.18 ±0.14	6.30 ±0.06	0.64 ±0.03	9.64 ±0.33	3.25 ±0.11	70.99 ±1.61
WDSF	6.50 ±0.05	6.00 ±0.13	0.40 ±0.03	10.10 ±0.10	3.10 ±0.03	73.90 ±0.02
FDSF	9.56 ±0.37	6.47 ±0.10	0.63 ±0.03	8.50 ±0.26	1.94 ±0.07	72.90 ±0.20
KWF	8.80 ±0.21	13.26 ±0.10	1.47 ±0.15	0.99 ±0.10	1.27 ±0.11	74.21 ±0.16

Note: NDS : native durian seed flour, WDSF: whole durian seed flour (Amin and Arshad, 2009); FDSF: fermented durian seed flour, KWF: korean wheat flour (Chung et al., 2010).

values for dried foods. The protein content of content of durian seed flour is about half of that of Korean wheat flour. This shows that the durian seed flour may not be appropriate for application in bread making; however, it could be suitable for the preparation of cookies, cakes or noodle. The lack of gluten in durian seed flour will be advantageous for people with celiac disease. The ash content of durian seed flour is more than two times of that of wheat flour, which indicates rich in mineral content. The reduction in ash content may be caused by either leaching of soluble minerals into water during fermentation or consumed by microorganisms that need nutrients and minerals for growth and development. As expected, the fat content of durian seed flour was low and comparable with the fat content in other tropical fruit seeds, such as jackfruit seed (0.94%) and cempedak (0.96%) (Meethal et al., 2017; Aziz and Zabidi, 2011). The fat content of wheat flour is about 2 – 2.5 times higher compared to that of native and fermented durian seed flour. From this point of view, durian seed flour is considered as a healthier raw material for food preparation compared to wheat flour. Compared to wheat flour, the fiber content in durian seed flour is about ten times higher in durian seed flour, which indicates that durian seed hull contained a lot of fiber. This indicated that durian seed flour has a promising potential to be used as a source of dietary fiber in the food industries. In addition to its high fiber content, the texture of native and fermented durian seed flour is less gritty compared to Korean wheat flour. Carbohydrate content of native durian seed flour obtained in this study was slightly lower than that reported by Amin and Arshad (2009). As expected, fermentation increased the carbohydrate content of fermented durian seed flour to a closer value to that of wheat flour (Chung et al., 2010) and jackfruit seed flour with brown spermoderm (75.8%) (Tulyathan et al., 2002).

CONCLUSION

A study on the effect of solid consistency (5 – 25% w/v), inoculum size (2.5 – 15% w/v) and time (0 – 40 h) on the submerged fermentation of durian seed chips using *Lactobacillus plantarum* has been successfully conducted. Obviously, fermentation changed all of the functional and thermal properties of durian seed flour. Fermentation increased the gelatinization temperature and oil absorption capacity of durian seed flour, but their value was still lower than that of wheat flour. The fermented durian seed flour obtained from fermentation of durian seed chips at 15% w/v solid consistency and 5% v/v inoculums size for 24 h is safe for consumption and exhibits similar functional properties to that of wheat flour. Therefore, durian seed flour offers

its advantages and high potential applications in the food industry to substitute wheat flour as raw material. However, further research needs to be conducted to ensure the acceptability and practical application of fermented durian seed flour as raw material for the manufacture of bread, cookies, cake and noodle.

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