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Functional Properties, Antioxidant Activities and Storage Stability of Cookies from Germinated Brown Rice and Rice-Potato Starch Composite Flour

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ABSTRACT

Cookies are convenient food for people of all ages. Consumers' interest for gluten free cookies is increasing recently due to awareness on gluten allergy. This study evaluated the functional properties and antioxidant activities of germinated brown rice flour (GBRF) and non-germinated brown rice flour (NGBRF), and GBRF-potato starch blend (3:1), and NGBRF-potato starch blend (3:1). Storage stability and sensory acceptance of cookies produced from the various flour samples were also evaluated. The flours had significantly different values in most of the functional properties. However, the Housner's ratio (1.18-1.35), Carr index (14.94-25.67) and water absorption index (1.88-2.14 g/g) of the flours were not significantly different. GBRF and germinated brown rice flour cookies (GBRFC) had the highest antioxidant activities with DPPH values of 40.61 µM TE/g and 37.67 µM TE/g, respectively, and FRAP values of 39.84 µM TE/g and 38.29 µM TE/g, respectively. The GBRFC had higher total phenolic content (152.30 mg GAE/100g) than cookies from GBRF-starch blend (107.37 mg GAE/100 g). Sensory evaluation results showed that all the cookies were similarly rated for aroma, texture, mouth feel, crispiness and overall acceptance. However, cookies prepared from wheat flour, and germinated brown rice-potato starch (GBRPS) had the highest sensory scores for overall acceptance. The hardness of cookies produced from GBRPS was similar to that of the freshly produced cookies after 7 days of storage at room temperature.

Keywords: Antioxidant activities, brown rice cookies, functional properties, germinated brown rice flour, pasting properties, storage stability

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INTRODUCTION

Rice is a very popular and important cereal crop consumed as staple food in most part of the World. Rice flour is recently becoming an important ingredient in food formulation (because of its gluten-free properties) for patients allergic to gluten (Gujral et al., 2003). Rice flour has been used for making noodles (Tong et al., 2015), bread (Cornejo et al., 2015; Nakamura et al., 2010; Toufeili et al., 1994), cake (Orts et al., 2000), and cookies (Chung et al., 2014). However, in order to improve the quality of rice-based products, rice grains are subjected to germination process. Germinated rice has been reported to contain more vitamins, minerals, fibre, antioxidants and other bioactive compounds than raw rice (Usuki et al., 2007; Watanabe et al., 2004; Yodpitak et al., 2013). The process has been used to produce healthy foods (Kayahara, 2001) and enhance the quality of baked products from rice (Morita et al., 2007).

Antioxidant plays important role in protecting humans from degenerative diseases and aging (Arab et al., 2011). Phenolic compounds have been reported to exhibit free radical scavenging ability and antioxidant activity (Shashidi et al., 1992). In addition, it also helps in reducing cholesterol level through the prevention of lipid oxidative damage and LDL (low-density lipoprotein) (Morton et al., 2000), prevents the aggregation of platelet (Daniel et al., 1999), and reduces the risks of cancer and cardiovascular diseases (Martinez-Valverde et al., 2000; Newmark, 1996). Although common sources of phenolic compounds are vegetables and fruits, researches have shown that cereals are also excellent sources of phenolic compounds (Scalbert & Williamson, 2000).

Cookies consumption is becoming increasingly popular in all countries of the world due to its low cost, long shelf life and palatability. In order to increase the nutritive value of cookies, and provide healthy alternative to gluten based cookies many researchers are now focusing on either partial substitution (Kaur et al., 2017a; Noor Aziah et al., 2012) or total replacement of wheat flour (Bolarinwa et al., 2016; Inglett et al., 2015; Jan et al., 2016) with gluten-free flour in cookies preparation. Substitution of rice flour with buckwheat flour in cookies preparation improved the texture (hardness and fracturability) and overall acceptability of cookies (Hadnađev et al., 2013). In another study, cookies prepared from composite flour of wheat and pre-treated (heat-moisture treatment) germinated brown rice had better nutritional composition than 100% wheat cookies (Chung et al., 2014). Most studies on cookies preparation with germinated brown rice make use of composite flour (Chung et al., 2014).

Potato starch has unique physical and chemical properties that are essential for human nutrition. Its granules swell more readily, and form more viscous gel than other starches (Tomasik, 2009). Potato starch has been used to substitute wheat flour in bread making (Nemar et al., 2015). Previous report on cookies preparation from brown rice flour and potato starch composite flour only reported proximate composition of the flour and physical properties of the cookies (Bolarinwa et al., 2018). The aim of the study was to determine the functional properties and antioxidant activity of GBRF and GBRF-potato starch composite flour (GBRPS), antioxidant activity, sensory characteristic and storage stability of cookies from GBRF and GBRPS. Data obtained in this study would provide useful information for functional food products formulation from GBRF and GBRPS. The use of germinated rice flour and potato starch as ingredient for cookies will create varieties in gluten-free cookies, and increase the nutritional composition of gluten-free cookies.

MATERIALS AND METHODS

Materials

Rice paddies (variety CL2) from Rakyat Sekinchan, Malaysia were used for the rice flour preparation. All other ingredients (butter, sugar, salt and baking soda) for cookies preparation including potato starch were obtained from IOI City Mall, Selangor, Malaysia.

Preparation of Germinated Brown Rice Flour

Germinated brown rice flour was prepared as previously described by Bolarinwa et al. (2018). Paddies (1 kg) were washed and cleaned thoroughly using distilled water. Floating paddies were decanted and the remaining grains were soaked in distilled water for 24 h at ambient temperature. The water was decanted and hydrated grains were placed on moistened Whatman filter paper (No. 7). The filter papers were placed on a stainless steel tray inside a water bath set at 30°C. The grains were separated with thickness of 1 cm and watered with 10 mL distilled water 3 times daily. The grains were allowed to germinate until the radicle reached approximately 0.5-1.0 mm in length (this was achieved in 48 h). The germinated grains were dried in a universal oven at 55^{o}C for 2 h. The dried rice were dehusked using a dehusker (Motion Smith, Singapore), ground and sieved using a Haver EML digital plus test sieve shaker (Harver and Boecker, 59302, OELDE, Germany) to particle size of <200 µm.

Cookie Formulation and Preparation

Cookies were produced from (A) Non-germinated brown rice flour (NGBR); (B) Germinated brown rice flour (GBR); (C) NGBR-potato starch composite flour (3:1; rice:starch); (D) GBR-potato starch composite (3:1; rice:starch); and (E) Wheat flour. The composite blend ratio was chosen based on preliminary studies. Cookies were prepared according to standard analytical method of American Association of Cereal Chemists International (AACC) (2000) with some modifications. Butter (60 g) and sugar (40 g) were mixed in a heavy duty kitchen aid mixer (5K5SS, Michigan, USA) to form cream. Flour (100 g), sodium bicarbonate (1 g) and salt (1 g) were then mixed with the cream to form dough. The dough was moulded and baked at 170^{o}C for 10 min in an electric oven, cooled at ambient condition for 2 h and packed in low-density polyethylene bags prior to analyses.

Determination of Functional Properties of the Flour

Bulk Density and Tapped Density. The bulk and tapped density of the flours were determined as described by Wang et al. (2017). Each flour sample (5 g) was poured into a 10 mL graduated measuring cylinder. The tapped density was estimated as mass of the flour divided by volume of flour in the measuring cylinder (after tapping). Bulk density was estimated as the mass of flours divided by the volume of the flour in the measuring cylinder. Bulk and tapped density were expressed as grams per mL of flour sample.

Hausner's Ratio and Carr Index. Hausner ratio (*HR*) is an indicator of flour compaction while Carr index (*CI*) measures flour cohesiveness. Hausner's ratio and Carr index of the flours were determined according to Wang et al. (2017) method. Hausner ratio was determined by dividing tapped density of the flour by their corresponding bulk density, while the Carr index was determined as stated:

Carr index = (tapped density - bulk density) × 100/ tapped density

Water Solubility Index. Water solubility index (WSI) of the flour samples was determined according to Jan et al. (2016) with a slight modification. The flour (2 g) was added to 25 mL water to form a suspension which was vortex for 2 min. The suspension was left to sediment at room temperature for 30 min, after which it was centrifuged (3500 × *g*, 15 min). The supernatant was decanted in a pre-weighed moisture can and evaporated. WSI was calculated as the amount of dry solid in the supernatant expressed as percentage of the original sample weight.

Water Absorption Index and Oil Absorption Capacity. Water absorption index (WAI) and Oil absorption capacity (OAC) were determined as described by Jan et al. (2016). WAI and OAC were expressed as grams of water and oil held per gram of flour sample, respectively.

Pasting Properties. The pasting properties of the flour samples were evaluated according to the method described by Limpisut and Jindal (2002), using a Rapid Visco Analyzer. RVA pasting curve and pasting properties values were obtained from the instrument after the runs.

Sample Preparation for Antioxidant Activity and Total Phenolics. The flour (0.5 g) and ground cookies (0.5 g) were separately mixed with 10 mL methanol (80%, v/v) and incubated at 40^{o}C for 24 h. The mixture was centrifuged (3500 × *g*, 15 min) and the resulting supernatant was used to quantify the amount of DPPH, FRAP and total phenolic in the flour and cookie samples.

Antioxidant Activity.

DPPH (2, 2-diphenyl-l-picrylhydrazyl) Radical Scavenging Activity. The DPPH assay was carried out according to the method described by Thaipong et al. (2006) with some modifications. DPPH stock solution was prepared by dissolving DPPH chemical (2.3 mg) with 100 mL methanol (80% v/v) in amber bottle, and sonicated for 5 min. The flour and cookie samples (100 µL) were mixed with the DPPH stock solution (3.9 mL) in a capped glass tube, vortex (15 s) and kept in a dark place at room temperature for 2 h. The optical density of the mixture was recorded at 515 nm. Methanol solution (80%) was used as blank and trolox was used to construct standard curve. Results were presented in mM Trolox equivalent of dry weight of sample (TE/g).

FRAP (Ferric Reducing Antioxidant Power) Assay. The FRAP assay was conducted as described by Wong et al. (2006) with slight modifications. FRAP reagent consisted of acetate buffer (pH 3.6), TPTZ solution (10 mmol) in HCl (40 mmol) and iron (III) chloride solution (20 mmol) in proportions of 10:1:1 (v/v), respectively. The samples (100µL) were added to FRAP solution (2.85 mL) and allowed to react for 30 min in the dark. The colored products were vortex (1 min) and the optical density was recorded at 593 nm. Standard curve was constructed using Trolox. Results were presented in mM Trolox equivalent of dry weight of sample (TE/g).

Total Phenolic Compound Analysis. Total phenolic content of the germinated and non-germinated rice flour, the rice composite flours and cookies were determined by the Folin-Ciocalteu method described by Ragaee and Abdel-Aal (2006) with some modifications. The sample (250 µL) was allowed to react with Folin-Ciocalteu reagent (2.5 mL) and 2 mL of sodium carbonate (7.5% w/v). The mixture was kept in darkness for 2 h and vortex (2 min). Optical density was recorded at 765 nm. Standard curve was constructed using gallic acid. Results were presented as gallic acid equivalent of dry weight of sample (mg GAE/g).

Hardness and Moisture Content of Stored Cookies

Cookies hardness was measured at a distance of 5 mm using a cutting probe. The pre-test, test, and post-test speeds were 1.5, 2, and 10 mm/s, respectively. The maximum force required to break the cookies was recorded as the cookies hardness. Moisture content of the freshly baked and stored cookies was determined by drying ground cookie (2 g) at 105^{o}C to a constant weight, which was achieved at 16 h (Association of Official Analytical Chemists [AOAC], 2011).

Sensory Evaluation

The cookies were evaluated by thirty untrained panellists. The panellists were served with the cookies once and allowed to rinse their mouth with portable water after tasting each cookie. Scorecards were presented to the panellists for evaluating the following attributes of the cookies: appearance, color, texture, taste, mouthfeel, crispiness, aroma, and overall acceptability. The panellists were asked to rate the cookies on a 9-point hedonic scale, where 9 is equivalent to like extremely and 1 is dislike extremely.

Statistical Analysis

Data were expressed as mean value of triplicate analysis. Results obtained were subjected to analysis of variance, using Minitab (version 16). Means were separated using Turkey's multiple comparison tests with significant differences at $P < 0.05$. Sensory data were subjected to analysis of variance (ANOVA), means were separated using Duncan's multiple range test.

RESULTS AND DISCUSSION

Functional Properties of Germinated Brown Rice Flour and Rice-Potato Starch Composite Flour

Results of the functional properties are presented in Table 1. Generally, there were significant differences ($p < 0.05$) in the functional properties of the flours, except for Housner's ratio, Carr index and water absorption index. The bulk density (flour heaviness) of the GBR flour (sample B) was similar to that of the NGBR (sample A), while addition of potato starch to rice flour only increased the bulk density of the NGBR-potato starch composite flour (sample C). Crude fibre content of flours is directly related to their bulk density (Jan et al., 2016). According to Hanis-Syazwani et al. (2018), rice bran contains up to 8.6% crude fibre. Thus, similar values obtained for the bulk density of GBR and NGBR flour could be due to the presence of bran in the brown rice flours. The bulk density of wheat flour was significantly lower than that of the rice flour samples (Table 1).

Tapped density is a useful parameter for determining packaging requirement of the flour samples. The tapped density of the GBR flour was 3.4% lower than that of the NGBR flour but 7% higher than that of wheat flour (sample E) (Table 1). Lower tapped density recorded for GBR compared to NGBR could be due to the smoother texture of GBR which made it more compact compared to NGBR. However, the tapped density of the composite rice flours was not significantly different ($P > 0.05$).

Housner's ratio and Carr index are important parameters for the determination of flour blends flow ability, which is significantly affected by particle properties (Wang et al., 2017). The Housner's ratio and Carr index of all the flour samples and the control sample (wheat flour) were not significantly different ($p > 0.05$) (Table 2). This indicates that NGBR and GBR mixed uniformly with the potato starch and their size, spread, shape and surface were in conformity with that of wheat flour.

Results of the water solubility index (WSI) showed that GBR flour had the highest WSI (5.8 g/100 g), followed by NGBR (4.1 g/100 g) and wheat flour (3.4 g/100g) (Table 1). Higher value of WSI for GBR flour was probably due to its finer particles, uniform particle size flour and soluble components such as reducing sugar and free sugar (Choi et al., 2006; Kadan et al., 2008). Water absorption index (WAI) affects product moistness and texture. The

Table 1
Functional properties of germinated brown rice, non-germinated brown rice and rice-potato starch composite flour

Sample	Bulk density (g/mL)	Tapped density (g/mL)	Housner's ratio	Carr index	Water solubility index (g/100g)	Water absorption index (g/g)	Oil absorption index (g/g)
A	0.45b ± 0.02	0.59a ± 0.02	1.32a ± 0.06	23.86a ± 3.23	4.09b ± 0.7	1.98b ± 0.05	1.92a ± 0.03
B	0.45b ± 0.04	0.57c ± 0.02	1.27a ± 0.15	23.83a ± 5.19	5.78a ± 0.25	2.14b ± 0.02	1.87b ± 0.03
C	0.49a ± 0.04	0.58b ± 0.03	1.18a ± 0.06	14.94a ± 3.98	3.05bc ± 0.07	1.88b ± 0.04	1.79c ± 0.05
D	0.45b ± 0.01	0.58b ± 0.02	1.27a ± 0.04	20.92a ± 2.43	2.20c ± 0.21	2.01b ± 0.05	1.76c ± 0.00
E	0.40c ± 0.01	0.53d ± 0.00	1.33a ± 0.02	25.03a ± 1.32	3.43bc ± 0.53	3.03a ± 0.25	1.93a ± 0.02

Values are mean ± standard deviation (n = 3). Mean value with different letter (s) along the same column are significantly different ($p< 0.05$). A - Non-germinated brown rice flour; B – Germinated brown rice flour; C - Non-germinated brown rice and potato starch composite flour; D - Germinated brown rice and potato starch composite flour; E – Wheat flour

WAI of most of the flour samples was not significantly different ($p > 0.05$) except for the control sample (wheat flour). Wheat flour had the highest WAI (3.03 g/g) followed by GBR (2.14 g/g) and GBR-starch composite flour (2.01 g/g). This result indicates that germination process slightly increased the WAI of the GBR flour (Table 1).

Oil absorption index (OAI) is an important property that affects product crispness and appearance (colour, gloss, shape) (Joshi et al., 2015). The OAI of wheat flour was 3% and 0.5% higher than the OAI of GBR and NGBR, respectively. This indicates that cookies produced from wheat flour will be similar to those of NGBR in terms of crispiness, shape, colour and appearance, but slightly different from GBR flour cookies. Lower OAI obtained in the composite flours indicates that cookies from the flour will be crispier and are likely to have better shape than cookies from GBR and NGBR flour.

Pasting Properties

Pasting properties of the rice flours and the composite flours are shown in Table 2. Interestingly, the pasting curve of the rice flour and the composite flour were distinctive from each other. The NGBR (sample A) and NGBR-potato composite flours (sample C) had higher peak viscosity (PV), trough viscosity (TV), final viscosity (FV) and breakdown viscosity (BV), while GBR (sample B) and GBR-starch composite (sample D) had much lower PV, FV, and BV. Thus, NGBR and NGBR-potato composite flours had higher modes than the other flours (Figure 1). This could be due to the presence of unmodified bran in the NGBR and

NGBR-potato composite flours, which took longer and required higher temperatures to gelatinize, and imparted higher viscosities than the GBR bran components, which had been modified during germination process. The pasting temperature of the GBR and the NGBR flours were similar.

On the other hand, the composite rice flours had lower pasting temperature than that of the rice flours but higher than that of the wheat flour (Table 2). The peak time of the rice flours and their composite flours were not significantly different, however, wheat flour required slightly longer time (6.27 min) to attain peak viscosity. This could be as a result of high WAI in wheat flour (Table 1) coupled with reduced absorption and swelling ability of wheat starch granules (Ragee & Abdel-Aal, 2006) compared to the other flours (Figure 1).

Table 2
Pasting properties of germinated brown rice, non-germinated brown rice and rice-potato starch composite flours

Sample	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (RVU)	Pasting Temperature (°C)
A	3610	1813	1797	4038	428	5.6	80.65
B	874	256	618	703	-171	4.6	80.55
C	4315	1839	2476	3441	-874	5.20	70.4
D	655	235	420	486	-169	4.67	69.65
E	2999	1885	1114	3028	29	6.27	68.05

Values are mean ± standard deviation (n = 3). Mean value different letter(s) along the same column are significantly different ($p < 0.05$). A - Non-germinated brown rice flour; B – Germinated brown rice flour; C - Non-germinated brown rice and potato starch composite flour; D - Germinated brown rice and potato starch composite flour; E – Wheat flour

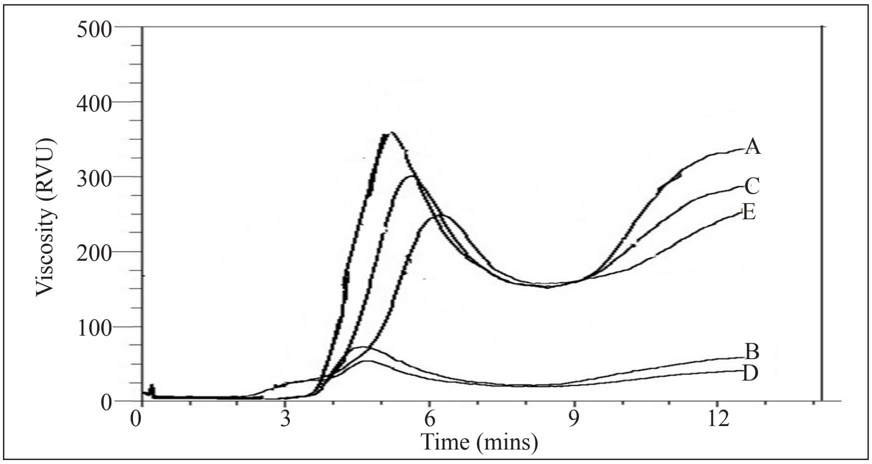


Figure 1. RVA pasting curves of germinated brown rice, non-germinated brown rice and rice-potato starch composite flour; A - Non-germinated brown rice flour; B – Germinated brown rice flour; C - Non-germinated brown rice and potato starch composite flour; D - Germinated brown rice and potato starch composite flour; E – Wheat flour

Antioxidant Activity of Germinated Brown Rice Flour and Rice-potato Starch Composite Flour

Numerous researchers have reported the antioxidants capacity of germinated brown rice from different rice varieties (Cho & Lim, 2016; Chung et al., 2016) and its health implications (Wu et al., 2013).

DPPH (2, 2-diphenyl-l-picrylhydrazyl) Radical Scavenging Activity

The DPPH-radical scavenging assays are used to estimate the capacity of an extract to donate electron/hydrogen to free radicals DPPH (Moon & Shibamoto, 2009). Germination significantly increased the DPPH, FRAP and Total phenolic of the flour and cookies. This could be because germination causes increased synthetic of high amount of powerful low-molecular-weight antioxidant molecules and accumulation of bioactive components such as antioxidants (Falcioni et al., 2002; Kaur et al., 2017b). There was significant difference ($p < 0.05$) in the DPPH value of both germinated and non-germinated flour and cookies (Table 3). Among all the samples, GBR and cookies (sample B) exhibited the highest DPPH radical scavenging activity. The radical scavenging activity was also significantly higher in germinated brown rice-starch composite flour and cookies (sample D) than that of non-germination brown rice (Table 3). This result is in congruent with previous study on antioxidant capacity of pigmented rice samples, where germinated rice samples were reported to contain significantly higher DPPH radical scavenging activity than non-germinated rice samples (Chung et al., 2016). Addition of potato starch to non-germinated rice flour and cookies increased the DPPH radical scavenging activity of the sample.

FRAP (Ferric Reducing Antioxidant Power) Assay

FRAP assay is a measure of the secondary antioxidant activity of sample extract (Chung et al., 2016; Vladimir-Knezevic et al., 2011). A significant high ferric reducing antioxidant power observed in germinated brown rice and germinated brown rice-potato starch composite flour and cookies, indicates that germinated samples had strong antioxidant potentials. These results are in agreement with previous study, which reported that germination process increased antioxidant activity in all germinated rough rice cultivars (Lee et al., 2007). Germination process has been reported to modify antioxidant activities of grains (López-Amorós et al., 2006). This could be because the colour of germinated rice grain is due to the accumulation of phenolics and flavonoid compounds which are responsible for increased in antioxidant activity in germinated grain (Gan et al, 2016). Generally, the FRAP antioxidant power of the rice flours (samples A and B) and the rice-starch composite flours (samples C and D) were significantly higher than that of the wheat flour (sample E). This could be due to relatively high antioxidant activity in brown rice (Esa et al., 2013).

Table 3
Antioxidant activity of germinated brown rice, non-germinated brown rice and composite flours and cookies

	DPPH (µM TE/g DM)		FRAP(µM TE/g DM)		Total phenolic(mg GAE/100 g)	
Sample	Flour	Cookies	Flour	Cookies	Flour	Cookies
A	35.61bc	34.78c	38.10b	35.33a	137.53a	138.67ab
B	40.61a	37.67a	39.84a	38.29a	151.80a	152.30a
C	36.42b	35.32b	36.57ab	33.90b	103.80b	107.37b
D	38.69ab	35.70ab	37.22ab	36.49a	113.17b	114.97ab
E	30.59c	30.07c	32.34c	31.10b	98.83b	119.80b

Values are mean ± standard deviation (n = 3). Mean value with different letter (s) along the same column are significantly different ($p < 0.05$). A - Non-germinated brown rice flour; B – Germinated brown rice flour; C - Non-germinated brown rice and potato starch composite flour; D - Germinated brown rice and potato starch composite flour; E – Wheat flour; DPPH – (2, 2-diphenyl-l-picrylhydrazyl) radical scavenging activity; FRAP - Ferric Reducing Antioxidant Power Assay

Total Phenolic Compound

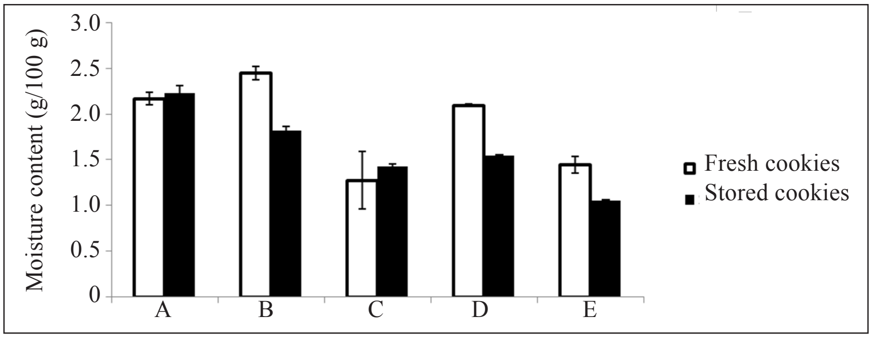
The total phenolic contents in germinated and non-germinated brown rice flour, rice-composite flours and cookies are shown in Table 3. The results showed that total phenolic compound contained in germinated brown rice flour (151.80 mg GAE/100 g) and cookies (152.30 mg GAE/100 g) were higher than those of the non-germinated brown rice flour (137.50 mg GAE/100 g) and cookies (138.67 mg GAE/100 g). Similarly, the total phenolic contents of germinated composite flour and cookies were higher than that of the non-germinated composite flour and cookies. These results are in congruent with the findings of Tian et al. (2004), who reported between one and two fold increment in phenolic compounds in germinated brown rice when compared with brown rice. On the other hand, the total phenolic compounds in all the rice flours and rice composite flours and cookies were higher than that of the control sample (wheat flour and cookie). In addition, higher phenolic compounds recorded for GBRF and GBRF cookies might be as a result of cell wall dismantling which occured during germination process (Tian et al., 2004). Higher total phenolic compound in germinated brown rice flour and germinated brown rice composite cookie suggests that the flour and cookies have higher antioxidant potential.

Generally, germinated brown rice flour and cookies exhibited higher antioxidant activities than the non-germinated samples as evidence in their DPPH, FRAP and total phenolic contents. This could be due to increase in the levels of rice phytochemicals as a result of germination (Chung et al., 2016).

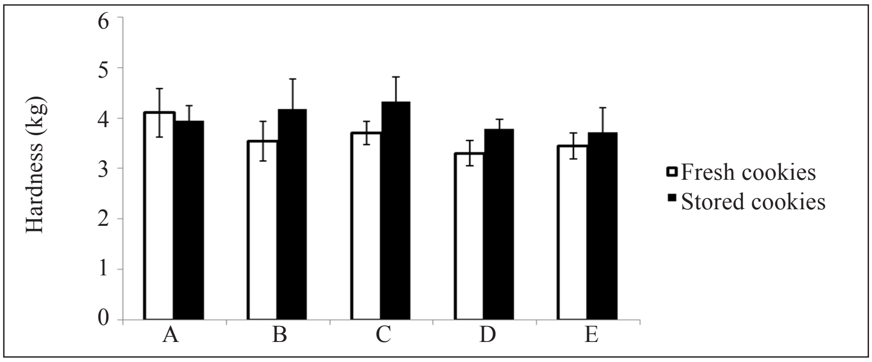
Changes in Moisture Content and Hardness of Stored Cookies

The storage stabilities of the cookies were evaluated after 7 days of storage at ambient condition. The moisture content of the non-germinated brown rice cookie (sample A) increased slightly from 2.17 g/100 g to 2.23 g/100 g while the moisture contents of the control (sample E) and the other cookie samples reduced significantly (Figure 2). This indicates that only cookies from non-germinated brown rice cookies absorbed moisture from the surrounding air while cookies from the germinated rice flour and composite flour lost moisture to the surrounding. Increased in the moisture content of stored non-germinated brown rice cookies may shorten the shelf-life of the cookies. Lower moisture content recorded for germinated brown rice and composite cookies compared to cookies from non-germinated rice flour is an indication that the cookies have different interior structures. Cookies containing germinated brown rice and potato starch composite flours might have much higher contents of fibers and degraded sugars as compared to those from non-germinated brown rice cookies. The simple sugars in germinated brown rice flour could hold cookies contents better and improve the internal structure of the cookies. Furthermore, reduced sugars or starch dextrins produced by germination process may retard starch retrogradation, inhibit sugar crystallization and cause little water migration during storage (Chung et al., 2014).

Addition of potato starch to germinated brown rice flour significantly reduced the hardness of the cookies, but slightly



(a)



(b)

Figure 2. Effect of storage on (a) moisture content and (b) hardness of cookies. A - Non-germinated brown rice flour; B – Germinated brown rice flour; C - Non-germinated brown rice and potato starch composite flour; D - Germinated brown rice and potato starch composite flour; E – Wheat flour

increased the hardness of non-germinated brown rice composite cookies (Figure 2). The hardness of the germinated brown rice cookies significantly increased from 3.54 kg to 4.18 kg after 7 days of storage at room temperature. However, addition of potato starch to the germinated cookies reduced the hardness of the cookies from 4.18 kg to 3.78 kg after storage. Lower moisture contents recorded for germinated brown rice cookies and the composite cookies could be responsible for increased hardness of the cookies. In addition, starch retrogradation may facilitate network formation which will be responsible for increase rigidity of the cookies, leading to increased hardness of the cookies. Previous study also reported similar observation for the hardness of stored cookies (Chung et al., 2014).

Sensory Evaluation

The sensory acceptance of cookies prepared from germinated brown rice, non-germinated brown rice, and rice-potato starch composite flour are presented in Table 4. There were no significant differences (p > 0.05) in the aroma, taste, texture, mouth feel, crispiness and overall acceptance of all the cookie samples. However, the control (100% wheat cookie) was significantly different (p<0.05) from all the rice cookies in terms of appearance and colour. Cookies prepared from non-germinated brown rice had sensory scores that were close to that of the control sample (Table 4). On the other hand, cookies from 100% germinated brown rice had the lowest sensory scores among all the samples. This could be due to distinguishable taste and flavor of germinated rice. Lower sensory score recorded for the colour of the germinated brown rice cookies could be due to high phenolic content (Table 3) in the cookies, which made it darker in colour compared to other samples. This observation is in agreement with previous study by Jan et al. (2016), who also attributed reduced sensory score for colour of cookies prepared from *Chenopodium album* flour to high phenolic content in germinated *Chenopodium album*

Table 4
Sensory scores of cookies prepared from germinated and non-germinated brown rice and rice-potato starch composite flours

Sample	Appearance	Color	Aroma	Taste	Texture	Mouth feel	Crispiness	Overall acceptance
A	6.77ab	6.57ab	6.53a	6.43a	6.50a	6.53a	6.73a	6.80a
B	5.86b	5.80b	6.17a	5.63b	6.23a	5.97a	6.27a	5.85a
C	5.93b	5.87b	6.50a	6.20ab	6.10a	6.33a	6.03a	6.23a
D	6.40ab	6.00ab	6.37a	6.33ab	6.63a	6.50a	6.63a	6.87a
E	7.27a	7.07a	6.40a	6.47a	6.93a	6.83a	6.67a	6.90a

Values are mean ± standard deviation (n = 30). Mean value with the same letter(s) along the same column are not significantly different (p > 0.05). A - Non-germinated brown rice flour; B – Germinated brown rice flour; C - Non-germinated brown rice and potato starch composite flour; D - Germinated brown rice and potato starch composite flour; E – Wheat flour

flour. However, addition of potato starch to germinated brown rice flour increased the sensory scores of germinated brown rice-composite cookies.

CONCLUSION

Germination and addition of potato starch to brown rice flour improved the functional and pasting properties of the flour. Germination significantly increased the DPPH, FRAP and total phenolic compounds in germinated brown rice flour, germinated brown rice-composite flour and germinated brown rice cookies. Substituting germinated brown rice with potato starch for cookies preparation resulted in better storage stability of the cookies. Cookies prepared from germinated brown rice flour had darker colour, distinguished flavor and aftertaste, however, addition of potato starch to germinated brown rice for cookies preparation effectively improved the sensory attributes of the cookies. Germinated brown rice-potato starch composite flour has the potential of replacing wheat flour in confectioneries and baked products.

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CONFLICT OF INTEREST

None.

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