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FULL PAPER

Quality of gluten-free cookies from germinated brown rice flour

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Abstract

Gluten-free food products are becoming popular due to increased consumers awareness on celiac disease. In this study, novel gluten-free cookies were produced from 100% germinated and non-germinated brown rice flour, and the blend of rice flour with 25% potato starch. The quality of the cookies was evaluated in terms of proximate composition, physical properties (diameters, weights, thickness and spread ratio), textural properties (dough and cookies hardness) and sensory attributes. Results obtained showed that germination increased the protein contents from 7.92% to 7.99%, ash from 1.29% to 1.38%, total dietary fibre from 5.27% to 6.13% and fat from 2.24% to 2.98% in germinated brown rice flour. Germinated brown rice dough and cookies had lower hardness value compared to non-germinated brown rice dough and cookies. Addition of potato starch to germinated brown rice flour increased the lightness (79.1-78.8) and yellowness (24.6-24.2) colour of the cookies, as well as the spread ratio of the cookies (8.28-8.37). Sensory evaluation results showed that all the cookies were similarly rated in terms of appearance, colour, aroma and taste, with cookies containing 75% germinated brown rice flour and 25% potato starch having the highest sensory score for texture (6.63) and overall acceptability (6.90). This study showed that the blend of germinated brown rice flour and potato starch can be used for the preparation of quality and acceptable gluten -free cookies.

1. Introduction

Consumption of convenience snacks is increasing recently in developing countries due to hustle and bustle lifestyles, and socioeconomic changes (Olumakaiye *et al*., 2010; Sekiyama *et al*., 2012; Abdullah *et al*., 2016). Cookies have therefore become one of the most desirable snacks in these countries. Cookies are flat, hard and crunchy foods made from basic ingredients such as flour, eggs and sugar (Norhidayah *et al.,* 2014). They possess longer shelf-life, are more convenient, low in cost and can serve as a vehicle for nutrients. Generally, commercial cookies are made from wheat flour. However, consumers' interests are now shifting from wheat based products to wheat free foods or gluten-free foods in order to prevent celiac disease (Rai *et al.,* 2011).

The use of rice flour in baking is popular nowadays because of its low cost and availability. In addition, grinding of broken rice grains into flour is a method of adding value to damaged or broken grains. Brown rice contains numerous nutritional and bioactive components including dietary fibre, lipids, amino acids, vitamin E, phytosterols, phenolic compounds, gamma-aminobutyric acid (GABA) and minerals (Cho and Lim, 2015). However, in the case of white rice, the milling process removes significant nutritional component of white rice. Thus, brown rice flour is a good choice in bakery products such as cookies because of its nutritional benefits. However, the addition of brown rice to cookies dough can cause cookies hardness. According to Cho and Lim (2015) and Wu *et al.* (2013), germination is the best way of solving these undesirable properties of brown rice, which includes rough eating texture, off-putting bran odour, low digestibility, and not-easy-to-cook problem.

Germinated rice flour is produced by soaking whole kernel of rice in water in order to boost germination or sprouting of paddies, thus, causing a 0.5–1.0 mm long sprout from the rice grain (Patil and Khan, 2011). During the process of germination, a number of biochemical processes take place due to the activation of various enzymes. These processes lead to change in nutritional and chemical compositions of germinated rice

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(Moongngarm *et al.,* 2014). Germination also leads to increase in bioactive compounds including antioxidants such as ascorbic acid, tocopherols, tocotrienols and gamma-aminobutyric acid in rice (Moongngarm and Saetung, 2010). According to Chung *et al.* (2014), enzymatic activities that occur during germination have been reported to increase organoleptic qualities of grains by contributing to the soft texture of cookies. In addition, germinated brown rice contains more health beneficial food components compared to milled rice (white rice). Germinated brown rice was reported to contain higher value of protein, fat and crude fibre than brown and white rice (Roy *et al.*, 2011). Germinated rice has also been reported to have better texture, easier to cook and has less cooking time (Shallan *et al.,* 2010; Yodpitak *et al.*, 2013). In terms of sensory attributes, cooked germinated brown rice is sweeter, softer, has high swelling capacity and is more cohesive than cooked regular brown rice (Patil and Khan, 2011). Therefore, germination is the key in solving hard texture of cookies from rice flour, where the addition of germinated brown rice flour is believed to aid in softening of rice cookies texture. In addition, germinated brown rice flours will contain higher nutrients than normal brown rice flour, as there are physiochemical changes during the process of germination, leading to the production of vitamins, mineral and bioactive compounds. Previous study showed that germinated brown rice contains about ten times more GABA, four time's dietary fibre, vitamin E, niacin and lysine, and about three times vitamins B1, B2 and magnesium than non-germinated brown rice (Roy *et al.*, 2011). Thus, the addition of germinated brown rice to cookies will increase the nutrient composition of cookies, contribute to increase availability of wheat-free cookies and add varieties to gluten-free cookies.

Although many studies have been done on germinated brown rice, there is limited information on cookies prepared from germinated brown rice flour. Therefore, the objectives of this study were to determine the nutrient composition of germinated brown and white rice flours, and to determine the physical properties, textural properties and consumers' acceptability of rice cookies.

2. Materials and methods

2.1 Materials

Rice flour was produced from paddies (CL2) obtained from PLS Marketing S/B, Sekinchan, Malaysia. Potato starch, butter, icing sugar, sodium bicarbonate and salt were obtained from a supermarket in Serdang, Selangor, Malaysia.

2.2 Methods

2.2.1 Production of non-germinated brown and white rice flour

Paddies (1 kg) were dehusked using a dehusker (Motion Smith, Singapore) to remove husk and convert the paddies into brown rice grains. The brown rice grains were ground into non-germinated brown rice flour (NGBRF) using a rice grinder (Good and Well Trading, Malaysia). For the non-germinated white rice flour (NGWRF), the brown rice grains were milled into white rice using a miller (Satake Testing Husker THU 35A, Singapore) and the white rice was ground into NGWRF using a rice grinder (Good and Well Trading, Malaysia). The rice flour samples were sieved using a Haver EML digital plus test sieve shaker (Harver and Boecker, 59302, OELDE, Germany) to particle size of <200μm.

2.2.2 Production of germinated brown and white rice flour

Rice paddies were germinated according to the method described by Premsuda *et al.* (2008), with some modifications. Paddy grains (1 kg) were washed and cleaned thoroughly using distilled water. Floating seeds were decanted and the good grains were soaked in distilled water for 24 hrs at room temperature. The water was decanted and hydrated rice grains were placed on moistened Whatman filter paper (No. 7). The filter papers containing the rice grains were placed on a stainless steel tray placed in a water bath 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 germinated for 48 hrs, at this time the radicle had reached approximately 0.5-1.0 mm in length. The germinated grains were dried in a universal oven at 55°C for 2 hrs. The dried rice was dehusked using a dehusker (Motion Smith, Singapore), ground and sieved as previously described for non-germinated brown rice flour (NGBRF) (section 2.2.1) to obtain germinated brown rice flour (GBRF). Germinated white rice flour (GWRF) was produced by milling GBRF, followed by sieving as previously described above.

2.2.3 Cookies preparation

Cookies were prepared according to the method of Jan *et al.* (2016) with slight modifications. Butter (60 g) and icing sugar (40 g) were mixed in a mixer (5K5SS Kitchen Aid, USA) until fluffy. Sodium bicarbonate (1 g), salt (1 g), rice flour (100 g) or the blend of rice flour (75 g) and potato starch (25 g) were added and mixed for 3 min. The dough was kneaded, sheeted to a uniform thickness of 0.5 cm and cut into round shape of 6.5 cm diameter. Cookies were baked at 170°C for 10 mins. The cookies were cooled at room temperature for 2 hrs prior to further analyses.

2.2.4 Proximate analysis of rice flour

The AOAC Method 960.52 method (AOAC, 2000) was used for crude protein (% N x 6.25) using a Micro-Kjeldahl equipment (KjeltecTM 4400 Analyser Unit, Sweden). Ash contents of the cookies were determined by dry ashing method according to AOAC method 923.03 (AOAC, 2000). Moisture was determined using air oven method of AOAC Method 934.01 (AOAC 2000). Total fat was determined using an automated Soxhlet method (FOSS Soxtec Automated System 2050, FOSS, Sweden) according to AOAC Method 963.15 (AOAC, 2000). Total Dietary Fibre was determined according to AACC Method 32-05.01 (AACC, 1999). Carbohydrate content was calculated by difference.

2.2.5 Physical analysis of cookies

2.2.5.1 Weight, diameter and thickness

Three cookies were picked randomly and each cookie was weighed using analytical balance before and after baking. The weight of the cookie was determined by calculating the average weight of the cookies. The diameter of the cookie was measured with a vernier calliper before and after baking. After the first measurement, the stack of cookies were rotated at 180° and new diameter was measured. The average of the two measurements divided by three was taken as the final diameter of the cookie. The thickness of the cookie was measured with a calliper before and after baking. After the first measurement, the stack of cookies were rotated at 90°, 180° and 270°, and new thickness was measured. The average of the four measurements divided by three was taken as the final thickness of the cookie (Noor Aziah *et al*., 2012).

2.2.5.2 Spread ratio

Cookies spread ratio was calculated according to the method of AACC Method 10-50.05 (AACC, 1999), by dividing the diameter of the cookies after baking by the thickness of cookies after baking.

2.2.5.3 Colour

Surface colour of the cookies was measured using a chromameter (CR-410, Konica Minolta, Japan) as described by Jan *et al.* (2016).

2.2.6 Texture analysis

2.2.6.1 Dough texture

The texture of both cookies and dough were determined by measuring their hardness using TX-XT2i Texture Analyzer (Texture Technology Crop., Scarsdale, New York, USA) according to Inglett *et al.* (2015). Dough hardness was measured by penetrating the dough (110 g) with a flat probe of 5 mm diameter using a TX-XT2i Texture Analyzer equipped with 5 kg load cell in compression mode. The hardness of the dough was tested using a pre-test speed of 2.00 mms^{-1}, test speed of 3mms^{-1}, post-test speed of 10.0 mm s^{-1}, and distance of 20 mm.

2.2.6.2 Cookies texture

Cookies hardness was measured by penetrating the cookie with a sharp-blade probe (6 cm long and 1 mm thick) using a TX-XT2i texture analyzer equipped with 30 kg load cell in compression mode. The test was conducted at a pre-test speed of 1.50 mms^{-1}, test speed of 2.0 mms^{-1}, post-test speed of 10.0 mm s^{-1}, and distance of 5.0 mm.

2.2.7 Water activity and moisture content of cookies

Water activity of the cookies was measured with Aqua Lab water activity analyzer (Decagon Devices Inc., Pullman, WA, USA). The moisture content of the cookies was measured by using air oven method of AOAC Method 934.01 (AOAC, 2000).

2.2.8 Sensory evaluation

The sensory attributes of the rice cookies were determined by thirty panellists comprising of students and staff of the Universiti Putra Malaysia (UPM). The cookies were evaluated for appearance, colour, aroma, taste, texture, and overall acceptance using a 9-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely).

2.2.9 Statistical analysis

Data were presented as means ± standard deviation. One-way analysis of variance (ANOVA) was used to estimate statistical significance differences between means at p-value ≤ 0.05 using Turkey's test. Minitab 16 software was used for the statistical analysis.

3. Results and discussion

3.1 Proximate composition of germinated and non-germinated rice flour

Table 1 shows the proximate composition of germinated and non-germinated brown and white rice flour. Germination resulted in increased in the protein and total dietary fibre contents of the rice flour. Germinated brown rice flour (GBRF) contained significantly higher protein, fat and dietary fibre than non-germinated brown rice flour (NGBRF). Higher protein, ash and dietary fibre contents in GBRF than NGBRF could probably be due to biochemical changes

Table 1. Proximate compositions and total dietary fiber contents of germinated and non-germinated brown and white rice flours

Parameter (g/100g)	NGBRF	GBRF	NGWRF	GWRF
Moisture	8.43±0.36[a]	8.61±0.36[a]	8.32±0.37[a]	8.91±0.63[a]
Ash	1.29±0.03[b]	1.38±0.05[a]	0.71±0.04[c]	0.66±0.01[c]
Protein	7.92±0.06[a]	7.99±0.04[a]	7.33±0.03[c]	6.60±0.75[d]
Fat	2.24±0.65[a]	2.98±0.12[a]	1.05±0.46[b]	0.83±0.13[b]
Total dietary fiber	5.27±0.46[b]	6.13±0.96[a]	3.20±0.48[c]	3.25±0.34[c]
Carbohydrate	80.12±0.95[b]	79.03±0.39[b]	82.59±0.53[a]	83.01±0.71[a]

NGBRF: non-germinated brown rice flour; GBRF: germinated brown rice flour; NGWRF: non-germinated white rice flour; GWRF: germinated white rice flour. Values are means ± standard deviations of triplicate analyses. Mean values along the same row with different superscript letters are significantly different (p< 0.05).

that occur as a result of activation of enzymes during germination, which led to the change in chemical compositions of germinated rice (Moongngarm *et al.,* 2014). Thus, increased in crude protein content in GBRF could be due to protease enzymatic activity during germination. During proteolysis, protein is degraded and hydrolysed into free amino acids which can be transformed into new protein compounds rapidly. This is usually measured during crude protein analysis, leading to increased crude protein content (Moongngarm and Saetung, 2010; Xu *et al.,* 2011; Wichamanee and Teerarat, 2012). Higher ash content in GBRF may be due to the formation of mineral content from enzymatic activities. Minerals such as magnesium, potassium and zinc are formed during germination process (Patil and Khan, 2011). Previous study also reported higher protein, fat and crude fibre for germinated brown rice (Roy *et al.*, 2011). The amounts of moisture, fat and carbohydrate in GBRF were not significantly different (p>0.05) from those of NGBRF (Table 1). On the other hand, the levels of the proximate components of germinated white rice flour (GWRF) were not significantly different from those of non-germinated white rice flour (NGWRF) except for the protein, which was significantly higher in NGWRF than GWRF. This could be because milling process removes the outer layer of rice bran, where most of the dietary fibre, oil, protein and other nutrients are found (El-Hissewy *et al.,* 2002).

3.2 Physical characteristics of rice and rice-potato composite cookies

3.2.1 Weight, diameter and thickness

The weight, diameter and thickness of rice cookies and rice-potato starch cookies are presented in Table 2. The weights of the 100% rice cookies were higher than those of the rice-potato starch composite cookies, with the non-germinated brown rice cookies (NGBRC) having the highest weight (9.17 g). Higher weight recorded for the NGBRC and the germinated brown rice cookies (GBRC) could be due to the presence of bran in the flour. This is probably because rice bran is rich in fibre (Roy *et al.*, 2011), which will add weight to the cookies. The diameter of the cookies ranged from 42 mm to 49.77 mm with significant differences between the diameter of the 100% rice cookies and the rice-potato composite cookies. The results presented in Table 2 also shows that addition of potato starch to rice flour resulted in significant reduction in the thickness of the rice cookies. This could be because potato starch is lighter in weight compared to rice flour.

3.2.2 Spread ratio

Cookies spread ratio is an important parameter for evaluating the rising ability of cookies. Cookies with low spread ratio will have better-rising ability than those with high spread ratio (Olapade and Adeyemo, 2014). As shown in Table 2, addition of potato starch to rice flour increases the spread ratio of the cookies. This indicates that rice cookies will have higher rising ability than rice-potato cookies. Although there were no significant differences (p>0.05) in the spread ratio of all the cookies, non-germinated white rice-potato cookies (NGWRPC) had the highest (8.50) spread ratio followed by germinated white rice-potato cookies (GWRPC) (8.37). Higher spread ratio recorded for GBRC (8.28) compared to NGBRC (7.76) could be due to high-fat contents in GBRF compared to NGBRF (Table 1). Previous studies attributed high-fat contents to high spread ratio (Agu *et al.*, 2014; Chen and Bhat, 2016). According to Mancebo *et al.* (2015), cookie dimensions can be affected by different proportions of flour, starch and protein. In this study, addition of potato starch resulted in larger spread ratio. However, cookies with larger spread ratio are more desirable (Okpala *et al.,* 2012; Barak *et al.,* 2014). Thus, rice-potato cookies with high spread ratio will be more acceptable to consumers than 100% rice flour cookies with low spread ratio.

3.3 Water activity, moisture content, and colour of cookies

3.3.1 Water activity

Water activity is a measure of free water in a food sample. It determines the microbiological stability, chemical reaction and properties of the baked products such as texture and sensory property. Baked products filled with various ingredients might have different water activity which may affect the microbial and sensory

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Table 2. Physical characteristics of rice and rice-potato starch composite cookies

	100% rice flour				75% rice flour + 25% potato starch			
	NGBRC	GBRC	NGWRC	GWRC	NGBRPC	GBRPC	NGWRPC	GWRPC
Weight (g)	9.17±0.97^{a}	8.47±0.06^{a}	8.53±1.82^{a}	8.30±0.14^{b}	8.12±0.13^{b}	8.23±0.12^{b}	8.02±0.05^{c}	8.23±0.06^{b}
Diameter (mm)	48.1±2.11^{a}	49.77±0.44^{a}	47.62±0.12^{a}	45.59±0.17^{a}	42.00±0.25^{b}	47.21±0.35^{a}	43.02±0.13^{b}	45.34±0.22^{b}
Thickness (mm)	6.20±0.65^{a}	6.01±1.71^{a}	6.11±0.34^{a}	5.68±0.63^{b}	5.41±0.13^{b}	5.64±0.09^{b}	5.06±0.10^{b}	5.53±0.11^{b}
Spread Ratio	7.76±0.07^{a}	8.28±0.09^{a}	7.79±0.12^{a}	8.02±0.34^{a}	7.76±0.40^{a}	8.37±0.04^{a}	8.50±0.10^{a}	8.19±0.11^{a}

NGBRC - non-germinated brown rice cookies; GBRC- germinated brown rice cookies; NGWRC- non-germinated white rice cookies; GWRC- germinated white rice cookies; NGBRPC - non-germinated brown rice-potato cookies; GBRPC- germinated brown rice-potato cookies; NGWRPC- non-germinated white rice-potato cookies; GWRPC- germinated white rice -potato cookies. Values are means ± standard deviations of triplicate analyses. Mean values along the same row with different superscript letters are significantly different ($p < 0.05$).

Table 3. Water activity, moisture content and colour of rice and rice-potato starch composite cookies

	100% rice flour				75% + 25% rice flour			
	NGBRC	GBRC	NGWRC	GWRC	NGBRPC	GBRPC	NGWRPC	GWRPC
Moisture Content	2.18±0.07^{b}	2.45±0.31^{ab}	2.55±0.07^{a}	2.48±0.01^{a}	1.28±0.09^{b}	2.10±0.04^{a}	1.76±0.11^{b}	1.67±0.09^{b}
Water Activity	0.31±0.017^{a}	0.24±0.01^{b}	0.27±0.02^{b}	0.26±0.01^{b}	0.27±0.01^{a}	0.27±0.01^{a}	0.26±0.01^{a}	0.27±0.010^{a}
Colour								
L*	74.35±0.71^{c}	79.06±0.77^{b}	81.93±0.76^{a}	82.71±0.77^{a}	78.27±2.17^{b}	78.76±1.46^{b}	80.88±1.97^{ab}	85.02±0.52^{a}
a*	6.33±0.46^{a}	5.16±0.66^{a}	4.53±0.37^{a}	4.27±0.66^{a}	4.60±0.74^{a}	4.23±1.07^{a}	5.60±0.35^{a}	5.21±0.97^{a}
b*	23.35±0.21^{c}	24.55±0.28^{b}	26.47± 0.23^{a}	26.48±0.24^{a}	24.58±0.44^{ab}	24.17± 0.23^{b}	26.39± 0.56^{a}	23.14±1.22^{b}

NGBRC - non-germinated brown rice cookies; GBRC- germinated brown rice cookies; NGWRC- non-germinated white rice cookies; GWRC- germinated white rice cookies; NGBRPC - non-germinated brown rice-potato cookies; GBRPC- germinated brown rice-potato cookies; NGWRPC- non-germinated white rice-potato cookies; GWRPC- germinated white rice -potato cookies. Values are means ± standard deviations of triplicate analyses. Mean values along the same row with different superscript letters are significantly different ($p < 0.05$).

Table 4. Hardness of rice and rice-potato starch composite cookies

	100% rice flour				75% rice flour + 25% potato starch			
	NGBRF	GBRF	NGWRF	GWRF	NGBRP	GBRP	NGWRP	GWRP
Dough Hardness (kg)	1.53±0.93^{a}	1.02±0.84^{b}	0.94±0.88^{b}	0.96±0.43^{b}	0.84±0.06^{a}	0.60±0.09^{b}	0.71±0.01^{a}	0.59±0.05^{c}
Cookies Hardness (kg)	5.94±0.35^{a}	5.11±0.56^{a}	5.16±0.64^{a}	4.50±0.45^{a}	3.60±0.61^{b}	1.60±0.25^{c}	6.02±0.32^{a}	4.01±0.13^{b}

NGBRF: non-germinated brown rice flour; GBRF: germinated brown rice flour; NGWRF: non-germinated white rice flour; GWRF: germinated white rice flour. NGBRP: non-germinated brown rice-potato starch; GBRP: germinated brown rice-potato starch; NGWRP: non-germinated white rice -potato starch; GWRP: germinated white rice -potato starch. Values are means ± standard deviations of triplicate analyses. Mean values along the same row with different superscript letters are significantly different ($p < 0.05$).

properties of the product. The results of the water activity of the rice cookies (Table 3) showed that there were no significant differences (p>0.05) in the water activity of the rice-potato cookies, however, significant differences (p<0.05) existed in the water activity of the rice cookies, with higher water activity in NGBRC (0.31), while GBRC had the lowest water activity (0.24). This might be due to the production of hydrophilic molecules during enzymatic degradation that occurred during the germination process. Hydrophilic molecules bind with water and cause less free water in cookies. In general, the water activity (0.24-0.31) of all the cookies was within the recommended water activity (0.3) for microbiologically stable food (Beuchat, 1981).

3.3.2 Moisture content

Moisture content is a measure of free and bound water in food products. The moisture content of GBRC was higher than that of NGBRC in both formulations, however, significant differences existed in cookies from the rice-potato starch blend. These results were similar to that of Chung *et al.* (2014), who reported that germination slightly increased moisture content in brown rice cookies. This could be because enzymatic degradation produces small molecules, which raised the osmotic pressure and thus, made cookies retain relatively higher amounts of water. Hydrophilic molecules produced from enzymatic degradation bind with water and increase the bound water. Incorporation of potato starch into rice flour significantly affected the moisture contents of the rice-potato cookies (Table 3), with the cookies containing potato starch having lower moisture contents (1.28-2.10%) than 100% rice cookies (2.18-2.55%). This could be because starch is hydrocolloid in nature, and has the ability to bind with water and keep moisture in cookies (Berry, 2012).

3.3.3. Colour

Colour is an important attribute to be considered by consumers in determining cookies acceptability (Zucco *et al.,* 2011). Cookies colour is generally due to Maillard reaction, which occurred during baking. Starch dextrinization and caramelization, which are induced by heating can also affect cookies colour (Chung *et al.,* 2014). The colours of the rice and rice-potato cookies are presented in Table 3. The results obtained showed that germination process significantly affected the colour of the cookies. This could be due to enzymatic activities that occur during the germination process, which results in the hydrolysis of starch and protein into simple sugar and amino acids, respectively. The sugar and amino acids on the other hand, can induce Maillard reaction (Islam *et al.,* 2012), which is responsible for increased lightness and yellowness values in GBRC. Incorporation of potato starch to rice flour decreased the lightness (L*) of the GBRC but increased that of NGBRC. Thus, GBRC became lighter upon addition of potato starch while NGBRC became darker with the incorporation of starch (Table 3). Yellowness (b*) values of the GBRC and NGBRC cookies follows a similar trend. However, there were no significant differences in the redness (a*) value of all the cookies. This could be due to the enhancement of redness during the baking process (Cheng and Bhat, 2016).

3.4 Dough and cookies hardness

Dough hardness is important during handling and moulding of dough into shapes. Generally, it is often hard to handle dough which is too soft or too firm. Cookies dough must have sufficient cohesive and viscoelastic to hold together and separate cleanly when cut (Mancebo *et al.,* 2015). Therefore, desirable and suitable dough hardness is required to ease cookies moulding and cutting process. In addition, textural attributes of cookies are important for consumer acceptability, as they are closely related to the eating quality of the cookies. Hardness is the peak force to snap a cookie. Table 4 shows the hardness of the dough and cookies from germinated brown or white rice flours, and blend of germinated brown or white rice flours with potato starch. The results showed that hardness of GBRF dough and cookies was significantly lower than that of NGBRF. Addition of potato starch to germinated brown rice flour decreases the hardness of the dough and the cookies. The decrease in the hardness of the GBRF dough and cookies compared to the NGBRF could be due to high fat contents in GBRF (Cheng and Bhat, 2016). Higher protein content in GBRF than NGBRF could also be responsible for the softer texture of GBRF dough and cookies. Protein interaction during dough development has been reported to be responsible for soft dough texture (McWatters *et al*., 2003; Cheng and Bhat, 2016). This result showed that germination had significant effect on rice dough and cookies softening.

As shown in Table 4, GBRF and germinated white rice flour (GWRF) cookies were softer than NGBRF and NGWRF cookies, respectively, in both formulations. However, significant differences only existed in hardness of the rice-potato starch composite cookies. Thus, germination had great effect in softening the texture of both dough and cookies. This could be due to enzymatic degradation of macromolecule into small molecule during germination. Degradation breaks the long chain molecule into short chain molecule and causes weaker force. Thus, weaker matrix formation in dough and cookies are formed, thereby causing decrease in hardness of both dough and cookies (Chung *et al.,* 2012).

Table 5. Sensory evaluation of rice and rice-potato starch composite cookies

	100% rice flour				75% Rice flour + 25% potato starch			
	NGBRC	GBRC	NGWRC	GWRC	NGBRPC	GBRPC	NGWRPC	GWRPC
Appearance	6.77±1.19[a]	5.87±1.68[a]	6.40±1.50[a]	6.73±1.60[a]	5.93±1.51[a]	6.40±1.40[a]	6.70±1.53[a]	6.10±1.73[a]
Colour	6.57±1.36[a]	5.80±1.67[a]	6.30±1.73[a]	6.47±1.57[a]	5.87±1.50[a]	6.00±1.58[a]	6.73±1.36[a]	6.23±1.43[a]
Aroma	6.53±1.33[a]	6.17±1.66[a]	6.47±1.31[a]	7.00±1.26[a]	6.37±1.40[a]	6.50±1.55[a]	6.87±1.25[a]	6.37±1.61[a]
Taste	6.43±1.45[ab]	5.63±1.75[b]	6.13±1.59[ab]	7.10±1.27[a]	6.20±1.59[a]	6.33±1.67[a]	6.77±1.65[a]	6.57±1.25[a]
Texture	6.50±1.31[a]	6.23±1.72[a]	6.27±1.46[a]	6.70±1.60[a]	6.10±1.63[a]	6.63±1.40[a]	6.57±1.55[a]	6.47±1.63[a]
Overall Acceptance	6.80±1.06[a]	5.85±1.45[b]	6.23±1.28[ab]	6.87±1.60[a]	6.23±1.41[a]	6.90±1.14[a]	6.82±1.58[a]	6.53±1.48[a]

NGBRC - non-germinated brown rice cookies; GBRC- germinated brown rice cookies; NGWRC- non-germinated white rice cookies; GWRC- germinated white rice cookies; NGBRPC - non-germinated brown rice-potato cookies; GBRPC- germinated brown rice-potato cookies; NGWRPC- non-germinated white rice-potato cookies; GWRPC- germinated white rice -potato cookies. Values are means ± standard deviations of triplicate analyses. Mean values along the same row with different superscript letters are significantly different ($p< 0.05$).

In general, dough and cookies hardness were lower in the rice-potato starch cookies samples compared to 100% rice flour samples. This could be probably because potato starch causes dough and cookies softness. According to Berry (2012), starch can function as hydrocolloid where it can bind with water and keep moisture in cookies. Thus, the moisture content might affect the softening of dough and cookies made from rice -potato starch composite flour.

3.5 Sensory evaluation of rice and rice-potato starch composite cookies

The sensory attributes of cookies produced from rice flour and rice-potato starch composite blend are presented in Table 5. The results showed that cookies prepared from 100% rice flour were rated similar to cookies from rice-potato starch composite in all sensory characteristics evaluated, except for taste and overall acceptability. In contrary to the results of the instrumental analysis of texture, the texture of 100% non -germinated brown rice cookies (NGBRC) were rated slightly higher (6.50) than that (6.23) of 100% germinated brown rice cookies (GBRC), although, there was no significant difference ($p>0.05$) in the values. This could be because the panelists prefer the hard texture of the NGBRF cookies. The colour of the GBRC was slightly darker and had distinct flavour ,and taste which are not acceptable to the panelists. These characteristics could be responsible for lower rating of the GBRC than the NGBRC and the potato supplemented cookies.

In terms of taste and overall acceptability, 100% NGBRC were rated significantly higher than GBRC (Table 5). However, germinated brown rice potato cookies (GBRPC) were rated slightly higher than that of non-germinated brown rice potato cookies (NGBRPC) in terms of taste and overall acceptability (Table 5). This indicates that substitution of germinated brown rice flour with potato starch positively influenced the sensory attributes of the cookies.

4. Conclusion

Germination improved the nutrient content in brown rice compared to white rice flour. Germinated brown rice flour had higher protein, ash, dietary fibre and fat contents than non-germinated brown rice flour. Substitution of brown and germinated brown rice flour with potato starch produced better quality cookies in terms of texture, and also produced cookies with brighter and lighter colour. In addition, cookies from germinated brown rice and potato starch blend were more accepted by the panellists in term of all the sensory attributes evaluated in this study. Thus, germinated brown rice-potato starch composite flour can be a good alternative to wheat flour for preparation of quality and nutritional improved cookies. Apart from cookies, the composite flour can also be used for other baked products such as bread, muffin, brownies and cake.

Conflict of Interest

Authors have no conflict of interest.

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