International Food Research Journal 26(3): 893-901 (June 2019)

Journal homepage: *http://www.ifrj.upm.edu.my*

Physical and sensory qualities of gluten-free muffin produced from composite rice-pumpkin flour

[1*]Ho, L.-H., [2]Zainal Abidin, N. F. S., [3]Tan, T.-C. and [1]Noroul Asyikeen, Z.

[1]Department of Food Industry, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia
[2]Faculty of Agro-Industry, Chiang Mai University, Mae-Hea, Mueang, 50100 Chiang Mai, Thailand
[3]Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia

Article history

Received: 22 July, 2017
Received in revised form: 22 March, 2018
Accepted: 15 January, 2019

Keywords

Rice flour
Pumpkin flour
Gluten-free Muffin
Physical properties
Sensory evaluation

Abstract

The effect of partial substitution of pumpkin flour for rice flour on the physical properties and sensory attributes of gluten-free muffin were investigated. Pumpkin flour was used to replace 10, 15 and 20% rice flour in a control gluten-free muffin formulation (without pumpkin flour). The partial substitution of pumpkin flour for rice flour did not affect moisture content of gluten-free muffins. However, the pumpkin flour substitution caused significant reduction in water activity of gluten-free muffins. Results on the volume, specific volume and height of all gluten-free muffins showed no significant effect with the increasing percentage of pumpkin flour substitution. However, pumpkin flour substitution significantly reduced the firmness of composite muffins, and improved its springiness. The colour of crumb progressively became darker as the level of pumpkin flour substitution increased. Moreover, the results also showed that the substitution of pumpkin flour caused an increase in yellowness (b^*) value of crust and crumb of gluten-free muffin. Sensory evaluation indicated that all gluten-free muffins incorporated with pumpkin flour received similar score when compared to that of control.

Introduction

Gluten is the main structure-forming protein in wheat. It contributes to the viscoelastic properties of the dough or batter and thus, influence the appearance and crumb texture of many baked good (Rodriguez Furlán *et al*., 2015). However, people with coeliac disease are strictly prohibited from consuming foods containing gluten such as wheat, barley, rye and oats due to immunological reaction to gluten. According to Maghaydah *et al*. (2013), gluten ingestion causes damage to the small intestinal mucosal thereby seriously reducing the absorptive surface of the intestinal tract. This in turn leads to the malabsorption of many vital nutrients such as calcium, iron, folate and fat-soluble vitamins in coeliac patients. The only known treatment to prevent complications caused by coeliac disease is by adhering to a strict gluten-free diet (Gallagher *et al*., 2003). Therefore, gluten-free products, especially bakery products, were initially designed for coeliac patients. At present, the demand for gluten-free products keep increasing, and is purely motivated by health concerns. As a consequence, many researches have been carried out to develop gluten-free bakery products in order to offer a wide variety of gluten-free products with good nutritional quality, textural properties, palatability and sensory as well as long shelf life (Matos *et al*., 2014).

Muffin is a type of chemical- or air-leavened baked product. Muffins are among the bakery products that are highly appreciated by consumers due to their sweet taste, soft texture and convenience (Nurul Ain *et al*., 2016). The major attributes to determine the physical quality of muffins are appearance, colour and specific volume. According to Itthivadhanapong and Sangnark (2016), the physical quality of muffins often depends on many factors such as the ingredients used, the aeration of batters, and the techniques applied during mixing. Wheat flour is one of the main ingredients used to produce muffin. For this reason, coeliac patients are not able to consume this baked product (Matos *et al*., 2014). Therefore, gluten-free

*Corresponding author.
Email: holeehoon@yahoo.com ; holeehoon@unisza.edu.my

muffins have been commercially manufactured to resemble those made from wheat flour (Matos *et al*., 2014).

Rice flour is often used to produce gluten-free food products due to its bright colour, mild taste, ease of digestion and hypoallergenic property (Sciarini *et al*., 2010; Rodriguez Furlán *et al*., 2015). However, it has low amount of protein, fibre and fat contents (Rodriguez Furlán *et al*., 2015). Long-term adherence to gluten-free diet may lead to inadequate nutrient, with a negative impact on health outcome in coeliac patients (Tess *et al*., 2015). Therefore, there is need to improve the nutritional content of gluten-free products. This can be achieved by incorporating rice flour with alternative gluten-free flour from fruits or vegetables that are naturally abundant with nutrients. Noor Aziah and Komathi (2009) reported that fibrous material from fruits and vegetables could be incorporated into bakery products to confer particular nutritional and sensory attributes. In addition, fibre components may act as stabiliser, emulsifier, thickening and gelling agent on bakery products to improve its physical properties, i.e. appearance and texture.

Pumpkin (*Cucurbita maxima*) is available all year round in Terengganu, Malaysia, and it is growing in high yield. Pumpkin, a gluten-free plant source (Wongsagonsup *et al*., 2015), has been reported to have nutritional advantage in terms of dietary fibre (especially pectin), minerals, vitamins (especially vitamin A or ß-carotene) and other bioactive compounds (e.g. phenolic compounds and terpenoids) (Noor Aziah and Komathi, 2009). In addition, pumpkin flour is a good source of protein as it has been reported to have approximately 9% protein (Ptitchkina *et al*., 1998; See *et al*., 2007). Development of bakery products with attractive natural colours has been a prominent goal in the food industry. Carotenoids, especially ß-carotene, have been identified as the pigment responsible for the yellow-orange colour in pumpkin. This yellow-orange colour indicates the presence of vitamin A in pumpkin (Bhat and Bhat, 2013). The attractive colour imparted by pumpkin flour could improve the appearance of food. According to Pongjanta *et al*. (2006), incorporating pumpkin flour in bakery products (e.g., sandwich-bread, sweet bread, butter cake, chiffon cake, and cookies) improved their colour and sensory characteristics. Therefore, pumpkin flour could be incorporated into rice flour in gluten-free muffin for colour enhancement purpose.

According to Itthivadhanapong and Sangnark (2016), the use of rice flour in the production of gluten-free muffin could significantly reduce its ability to entrap air during mixing thereby resulting in unfavourable appearance, crumb texture in terms of softness and springiness of baked products, and acceptance by consumers. Maintaining and enhancing the quality of muffin is therefore paramount. Recently, pumpkin flour was used in the processing of bread by partial substitution for wheat flour. Breads containing pumpkin flour have been shown to improve the loaf volume and organoleptic acceptability (See *et al*., 2007). Significant enhancement in loaf volume of wheat bread containing pumpkin flour was also observed by Ptitchkina *et al*. (1998). However, there is no information on the effect of partial substitution of pumpkin flour for rice flour on the physical and sensory qualities of gluten-free muffin. Therefore, pumpkin flour could be incorporated into rice flour to compensate the aforementioned drawbacks of using rice flour to produce gluten-free bakery products. The objective of the present work was therefore to investigate the physical and sensory qualities of rice flour muffins formulated with partial substitution with pumpkin flour.

Materials and methods

Materials

All ingredients (i.e., pumpkin, rice flour, sugar, egg, milk, baking powder, butter) for gluten-free muffin making were purchased from a local supermarket (Supermas Supermarket) in Besut, Terengganu, Malaysia. All chemicals used were of analytical grade.

Methods

Processing of pumpkin flour

Pumpkin flour was prepared according to the procedure described by Noor Aziah and Komathi (2009). Pumpkin was rinsed under running tap water to remove dirt, foreign matter and soil. The skin of the pumpkin was peeled manually using a fruit peeler. Then, the pulp was cut into small pieces prior to soaking in the sodium metabisulphite solution (0.1%, w/v) for 45 min to delay enzymatic browning. The cut pulp was thoroughly washed using distilled water and then sliced into 2 mm thickness using a fruit slicer (Santos, Vegetable Slicer 48, Lyon, France) before drying in a ventilated dryer (Tech-Lab, FDD-720, Selangor, Malaysia) at 60°C for overnight. The dried pumpkin slices were ground using laboratory mill (Panasonic, MX-801S, Selangor, Malaysia) to produce fine powder and then sieved using sieve shaker (Endecott, Octagon 200, London, UK) at 200 mm diameter of mesh sieve with 250 µm aperture size to obtain uniform pumpkin flour particle size. The fine pumpkin flour was kept in an airtight plastic container and stored at room temperature prior to analysis.

Processing of muffin

All gluten-free muffins were prepared according to the method proposed by Tess *et al*. (2015) with slight modification on the formulation. Gluten-free muffins were prepared according to the formulations shown in Table 1. Rice flour was substituted by increasing the amounts of pumpkin flour (10, 15, 20%) to prepare GFM10, GFM15 and GFM20, respectively. Gluten-free muffin without pumpkin flour served as control (GFM0). Sugar and butter were creamed until soft and creamy. Then, other liquid ingredients (i.e., egg and milk) were added into the mixture and further mixed until light and fluffy using a hand mixer (Philips, HR1456/70, Toa Payoh, Singapore). In a separate bowl, all dry ingredients such as rice flour, pumpkin flour and baking powder were thoroughly mixed. Later, the dry ingredients were sifted and folded gently into the wet ingredients. Approximately, 40 ± 1 g batter was then poured to the round paper cup (50 mL) and baked in an electric multideck baking oven (Schneider Electric, MBE-203E-Z, Paris, French) at 180°C for 30 min. The baked gluten-free muffins were cooled at room temperature for 1 h prior to analysis.

Table 1. Formulations of gluten-free muffin.

Ingredients	Types of muffin[1]			
	GFM0	GFM10	GFM15	GFM20
Rice Flour (g)	100	90	85	80
Pumpkin flour (g)	0	10	15	20
Sugar (g)	60	60	60	60
Butter (g)	57	57	57	57
Egg (g)	79	79	79	79
Baking powder (g)	5	5	5	5
Milk (mL)	56	56	56	56

[1]GFM0 (control), GFM10, GFM15 and GFM20 represent gluten-free muffin made from pumpkin flour substituted for rice flour at 0, 10, 15 and 20%, respectively.

Determination of moisture content

The moisture content of the gluten-free muffins was determined according to Oven Drying Method (AOAC Official Method 977.11). Approximately 5 g sample was spread evenly on a pre-dried crucible and then dried at 105°C in an oven overnight. Re-drying process continued for every 1 h interval until the samples weight showed difference of less than 2 mg compared to previous recorded reading (AOAC, 1995).

Determination of water activity

The water activity of gluten-free muffins was determined using a water activity meter (AquaLab, Series 4TE, Washington, USA) at 25°C. Approximately 2 g sample was spread evenly on a retronic cup, and was allowed to equilibrate within the headspace of the sealed chamber. The reading was then recorded when equilibrium was achieved.

Determination of height, volume, and specific volume

The height (expressed in cm) of gluten-free muffins was measured using a ruler. Three measurements were taken from different sides of muffin. The average of the three readings was recorded. The volume (expressed in cm3) and specific volume (expressed in cm3/g) of gluten-free muffin were analysed by using a benchtop laser-based scanner (VolScan Profiler, Stable Micro Systems Ltd, Surrey, UK), which is a rapid method used to assess the volume and specific volume of the sample. A non-contact measurement system was selected in the volume and specific volume measurement with using 3-dimensional assessment of soft and freshly baked products. The support pins was inserted at the centre of the largest diameter of muffin. Then, it was placed on the product support platform and transferred onto turntable. The support pin from the top arm of VolScan Profiler was inserted into the crumb of muffin for support. The muffin was then automatically weighed, and an eye-safe laser device was used to scan vertically to measure the contours of the muffin whilst it rotated. The data were generated using VolScan Profiler Software (Stable Micro Systems Ltd, Surrey, UK).

Texture profile analysis

Texture profile analysis of gluten-free muffins was measured using a texture analyser (Stable Microsystem, TA–XT2i, Surrey, UK) with a load cell of 2 kg weight based on Method 74-09 (AACC, 2000). The gluten-free muffins were cut into 8 cm3 cube size from the middle of the muffin using a clean bread knife. The cut samples were placed centrally beneath the P/36R cylinder probe (36.0 mm) to meet with a consistent flat surface at entire analysis. The samples were analysed by compression test using 5 kg load cell. The samples were measured under the force of compression at 25% of the product original height with duration of 30 s of evaluation. The hardness and springiness were analysed using Texture Expert Version 1.05 Software (Stable Micro System Ltd, Surrey, UK).

Determination of colour

The crust and crumb colour of gluten-free muffins were determined according to lightness (L^* = 100; white and L^* = 0; black), Chroma a^* [green chromaticity (-60) to red (+60)], and Chroma b^* [blue chromaticity (-60) to yellow (+60)] space value using a colorimeter (Konica Minolta, Chroma Meter CR-400, Tokyo, Japan).

Sensory evaluation

Sensory evaluation for gluten-free muffins was performed by 30 semi-trained panellists (students and staffs) from the Department of Food Industry, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Malaysia. A preference test using a 7–point hedonic scale was adopted to evaluate the sensory acceptability by panellists (Watts *et al*., 1989), where point 1 indicated dislike very much to point 7 which indicated like very much. The gluten-free muffins were cut into 8 cm3 cube size using a clean bread knife. The muffins were then placed onto white plate labelled with randomised 3-digit numerical codes. Each sample was presented to the panellists in the randomised order to prevent bias. Each panellist was provided a plate of labelled samples, a cup of drinking water, and a sheet of sensory form. The panellists were requested to rate the gluten-free muffins on the scale for the following attributes; colour, aroma, crumb texture, crumb moistness, sweetness and overall acceptability.

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 14.0 software (SPSS Inc., Chicago, IL, USA). The obtained results are represented as mean values of three individual replicates ± standard deviation. Significant differences between the mean values were determined using Duncan's multiple range tests at a significance level of 0.05 ($p < 0.05$).

Results and discussion

Moisture content and water activity of gluten-free muffins

Moisture content and water activity are the two main parameters of food products that influence their shelf life. According to Rakcejeva *et al*. (2011), the shelf life of products with high moisture content is shorter than that with lower moisture. The partial substitution of pumpkin flour in gluten free muffins did not affect the moisture content (Table 2). Moisture content is defined as the free water in the food that could be evaporated after drying, i.e. baking (Bradley, 1998). Since the initial water content was closely similar for all gluten-free muffins prepared in the present work, it was therefore expected that these muffins would have similar water losses during baking under similar baking temperature. These results agree with those reported by Rakcejeva *et al*. (2011) where the control bread (without pumpkin flour) had similar moisture content with bread incorporated with pumpkin flour. However, Ptitchkina *et al*. (1998) reported that the addition of pumpkin flour at concentration up to 10% level of wheat flour caused an increase in moisture content of bread. A similar trend was observed in a study completed by See *et al*. (2007) in which the increase in the level of pumpkin flour in bread resulted in the increase of moisture content of the produced bread. The increase in the level of pumpkin flour caused significant increase ($p < 0.05$) in the moisture content of gluten-free muffins. This could be due to the higher water absorption capacity of the pumpkin flour as compared to that of wheat flour, which is in accordance with the findings of See *et al*. (2007).

Table 2. Moisture content and water activity of gluten-free muffins formulated with various levels of pumpkin flour.

Parameters	Types of muffin[1]			
	GFM0	GFM10	GFM15	GFM20
Moisture[2]	28.41^a ± 0.77	29.43^a ± 1.30	28.47^a ± 0.35	30.24^a ± 1.14
Water activity	0.93^a ± 0.01	0.91^b ± 0.00	0.91^b ± 0.00	0.91^b ± 0.00

Data are mean ± standard deviation (n = 3). Values with different superscript letters within a row are significantly different ($p < 0.05$). [1]GFM0 (control), GFM10, GFM15 and GFM20 represent gluten-free muffin made from pumpkin flour substituted for rice flour at 0, 10, 15 and 20%, respectively. [2]Moisture was reported in % wet basis.

Water activity is an important parameter in determining the quality and safety of food products. It is defined as water associated with other constituents in a matrix that makes it unavailable for chemical reactions and microbial growth (Bradley, 1998). Gluten-free muffins incorporated with pumpkin flour (i.e., GFM10, GFM15, GFM20) showed significantly lower ($p < 0.05$) water activity than that of control (Table 2). This could be attributed to the presence of low molecular weight constituents, such as sugars and acids, which rendered the pumpkin flour to be more hygroscopic than rice flour (Deshmukh *et al*., 2017). These hygroscopic constituents readily attract water from its surroundings through either absorption or adsorption. Thus, water tightly associated with sugar constituents of pumpkin flour caused it to be unavailable (low water activity). According to Smith and Simpson (1995), food product with water activity value above 0.85 can be classified as moist food product. Thus, all the produced gluten-free muffins fell into the moist food category. Therefore, these muffins are susceptible to microbial spoilage. This finding is in agreement with that reported by Wongsagonsup *et al*. (2015) in which breads produced with composite wheat-pumpkin flour had water activity value ranging from 0.942 to 0.953.

Height, volume, specific volume, and textural properties of gluten-free muffins

Physical properties of baked products influence greatly on the buying decision of consumers. The results obtained showed insignificant difference ($p > 0.05$) in the sample height between gluten-free muffins containing pumpkin flour (i.e., GFM10, GFM15, GFM20) and control (Table 3). This is in-line with the finding by Baker *et al*. (2013) who reported that the substitution of quinoa flour for rice flour had no influence on the height of the gluten-free muffins. However, this finding contradicts with the finding reported by Tess *et al*. (2015) where a decrease in height of baked gluten-free muffins resulted from the increase in the substitution percentage of teff flour for rice flour. In addition, the increased in percentage of banana flour in gluten-free muffin showed lower line spread, which contributed to a decrease in height of baked muffins (Ng *et al*., 2012). Based on these comparisons, pumpkin flour showed to be a good flour substitute, and that the partial substitution of pumpkin flour for rice flour had no negative influence on the height of gluten-free muffin, i.e. no decrease in the height of the muffin.

The volume of gluten-free muffins ranged from 42.08 to 43.69 cm3 (Table 3). These results agree with those reported by Baker *et al*. (2013) in which the substitution of quinoa flour for rice flour did not affect the volume of the composite gluten-free muffins. These findings are expected due to the fact that these types of flour used are gluten-free flour (Gujral *et al*., 2003). According to Lazaridou *et al*. (2007), gluten is an essential structure-building protein contributing to the appearance and crumb structure of many baked products. Thus, the absence of gluten in the gluten-free formulation led to no significant changes ($p > 0.05$) in the volume between control (i.e., GFM0) and gluten-free muffins containing pumpkin flour, i.e GFM10, GFM15 and GFM20 (Table 3). However, See *et al*. (2007) reported that the substitution of pumpkin flour for wheat flour at 5% significantly increased the volume (914.50 mL) of composite bread.

Specific volume of gluten-free muffins incorporated with pumpkin flour ranged from 2.00 to 2.13 cm3/g (Table 3). No significant changes ($p > 0.05$) were observed on the specific volume of muffins with the partial substitution of pumpkin flour for rice flour at level up to 20%. This lack of influence of pumpkin flour on the specific volume is in agreement with Matos *et al*. (2014) who reported that the substitution of various types of protein flours (i.e., vital wheat gluten and soy protein isolate) for rice flour in muffins preparation had no influence on the specific volume of gluten-free muffins. However, specific volumes of gluten-free muffins containing pumpkin flour showed higher value than the findings reported by Matos *et al*. (2014) in which their rice-based muffins incorporated with different protein sources had specific volume of 1.54 cm3/g. This finding shows that pumpkin flour could be a good flour substitute for rice flour in producing gluten-free muffin since pumpkin flour has been shown to contain higher amount (at 3.36%) of crude fibre, i.e. pectin (Wongsagonsup *et al*., 2015), when compared with other protein flour, such as soy protein isolate (only 0.5%) (Codex Standard, 2018). According to Ptitchkina *et al*. (1998), the surface activity of highly acetylated pectin in pumpkin flour is responsible for the stabilisation of gas-cell structure of baked products. Thus, partial substitution of pumpkin flour for rice flour resulted in the enhancement of the specific volume of these muffins.

Gluten-free muffins containing pumpkin flour (i.e., GFM10, GFM15, GFM20) showed no significant effect ($p < 0.05$) on the height, volume and specific volume of the muffins. Results obtained in the present work suggest that pumpkin flour acted by enhancing gas-cell stability, which comes from surface activity of pumpkin pectin rather than by

Table 3. Physical properties of gluten-free muffins formulated with various levels of pumpkin flour.

Physical Properties	Types of muffin[1]			
	GFM0	GFM10	GFM15	GFM20
Height (cm)	$55.43^a \pm 0.87$	$54.78^a \pm 0.15$	$54.98^a \pm 1.24$	$55.48^a \pm 0.14$
Volume (cm^3)	$43.69^a \pm 2.18$	$43.46^a \pm 0.61$	$42.08^a \pm 0.19$	$43.45^a \pm 0.93$
Specific volume (cm^3/g)	$2.13^a \pm 0.09$	$2.09^a \pm 0.00$	$2.00^a \pm 0.04$	$2.07^a \pm 0.07$
Hardness (g)	$1,275.48^a \pm 85.61$	$935.23^b \pm 126.81$	$1,029.84^b \pm 114.75$	$961.81^b \pm 47.55$
Springiness	$54.40^a \pm 2.56$	$59.34^b \pm 0.74$	$58.52^b \pm 1.29$	$57.79^a \pm 2.54$

Data are mean ± standard deviation ($n = 3$). Values with different superscript letters within a row are significantly different ($p < 0.05$). [1]GFM0 (control), GFM10, GFM15 and GFM20 represent gluten-free muffin made from pumpkin flour substituted for rice flour at 0, 10, 15 and 20%, respectively.

increasing the strength of the surrounding matrix (Ptitchkina *et al*., 1998). Furthermore, pumpkin has approximately 30% (dry weight basis) pumpkin tissue (Ptitchkina *et al*., 1998). The pectin of pumpkin is highly acetylated (approximately one acetyl group per four galacturonate residues) and shows hydrophobic characteristic. Higher degree of acetylation of pectin is desirable to stabilise emulsions and foams. It would therefore be expected that pectin in pumpkin flour acts as an interfacial agent in air-water and oil-water systems (Ptitchkina *et al*., 1998) in maintaining the structure of the muffins.

Gluten-free muffins containing pumpkin flour (i.e., GFM10, GFM15, GFM20) showed significantly lower ($p < 0.05$) hardness than that of control, (Table 3). According to Nilufer-Erdil *et al*. (2012), the addition of fibre to bakery products can enhance the softness of the crumb by binding and retaining water during baking. Pumpkin flour has been reported to contain higher crude fibre (at 3.36%) than that of rice flour, ranging between 0.46–0.92% (Kataria, 2014; Wongsagonsup *et al*., 2015). The major components in crude fibre of pumpkin flour are pectin (18.7%), cellulose (40.4%), hemicelluloses (4.3%) and lignin (4.3%) (Ptitchkina *et al*., 1998). Therefore, the enhancement of crumb softness could be due to the presence of higher fibre content in pumpkin flour than in rice flour. The springiness of gluten-free muffins was improved by partial substitution of pumpkin flour for rice flour. The springiness of control was significantly lower ($p < 0.05$) than those of gluten-free muffins containing pumpkin flour, i.e. GFM10, GFM15, and GFM20 (Table 3). In the present work, the springiness of muffin showed inverse relationship with its hardness. From these results, it could be concluded that the increase in hardness led to the decrease in springiness. This trend is similar to that reported by Matos *et al*. (2014), in which rice-based muffin with the addition of pea protein isolate showed the lowest hardness and highest springiness.

Colour characteristics of gluten-free muffins

Colour enhances the appearance of food, giving it an aesthetic value and an appetising contrast (Abdullah, 2008). The results of colour measurement indicated that the crust lightness value (L^*) of muffins containing pumpkin flour (i.e. GFM10, GFM15, GFM20) was insignificantly different ($p > 0.05$) from that of control (Table 4). According to Ho *et al*. (2013), the crust colour is mainly caused by Maillard reaction during baking. Montaño *et al*. (1999) reported the presence of protein in both rice (at 7.6%) and pumpkin (at 9.69%) flours. Even though the amount of protein differs between these two types of flour, the substitution of pumpkin flour for rice flour at level up to 20% showed no influence of the pumpkin flour to the lightness of the crust of the muffins. In addition, the crust experienced rapid loss of moisture at elevated temperature, which contributes to the darkening of crust as compared to that of crumb (González-Mateo *et al*., 2009).

Crumbs from muffins containing pumpkin flour (i.e. GFM10, GFM15, GFM20) had significantly lower ($p < 0.05$) L^* than that of control (Table 4). Crumbs from muffins containing pumpkin flour changed from white to brown. According to González-Mateo *et al*. (2009), the colour of the crumb is not dependent to the temperature of the oven, but usually imparted by the colour of the ingredients used, considering that the crumb does not reach high temperature as the crust. Hence, it is obvious that pumpkin flour imparted darker colour to the crumb of the muffins in the present work.

The redness (a^*) of the crust and crumb for all formulations showed insignificant difference ($p > 0.05$) from each other (Table 4). The a^* for the crust of all the produced gluten-free muffins were positive, which indicates that red hues were present in the crust of gluten-free muffins. In contrast, the a^* for the crumbs showed negative values, which indicates the colour of the crumb was green. These

Table 4. Colour of gluten-free muffins formulated with various levels of pumpkin flour.

Colour Parameters	Types of muffin[1]			
	GFM0	GFM10	GFM15	GFM20
Crust				
Lightness (L^*)	$59.79^a \pm 3.93$	$62.46^a \pm 4.36$	$65.45^a \pm 3.18$	$61.31^a \pm 2.60$
Redness (a^*)	$3.96^a \pm 1.46$	$2.13^a \pm 0.32$	$3.65^a \pm 2.57$	$4.42^a \pm 2.33$
Yellowness (b^*)	$41.78^a \pm 0.99$	$49.72^b \pm 2.31$	$56.20^c \pm 1.72$	$56.77^c \pm 1.80$
Crumb				
Lightness (L^*)	$73.12^a \pm 0.72$	$68.01^b \pm 1.34$	$69.74^b \pm 1.74$	$67.91^b \pm 1.06$
Redness (a^*)	$-5.52^a \pm 0.14$	$-5.55^a \pm 0.21$	$-5.63^a \pm 0.25$	$-5.16^a \pm 0.37$
Yellowness (b^*)	$26.12^a \pm 0.88$	$46.29^b \pm 2.96$	$49.28^b \pm 0.95$	$54.70^c \pm 1.08$

Data are mean ± standard deviation ($n = 3$). Values with different superscript letters within a row are significantly different ($p < 0.05$). [1]GFM0 (control), GFM10, GFM15 and GFM20 represent gluten-free muffin made from pumpkin flour substituted for rice flour at 0, 10, 15 and 20%, respectively.

results suggested that the incorporation of pumpkin flour into rice flour muffins had no influence on the reddish colour of the baked products. This is in-line with the results reported by Wongsagonsup *et al*. (2015) in which all breads made from wheat with or without incorporation of pumpkin flour had crumbs with negative a^* value.

Significant difference ($p < 0.05$) was observed for crumb and crust yellowness (b^*) between gluten-free muffins containing pumpkin flour (i.e. GFM10, GFM15, GFM20) and that of control (Table 4). GFM20 had the highest b^* value for crust and crumb. This could be associated to the yellow pigments, i.e. carotenoids, found in pumpkin, especially in the pulp, which is a rich source of β-carotene (See *et al*., 2007). Study performed by Rakcejeva *et al*. (2011) showed that wheat bread supplemented with pumpkin flour has approximately 1.5 times higher in b^* value than that of control, i.e. bread without pumpkin flour. Similar trend was observed by Wongsagonsup *et al*. (2015) for bread incorporated with pumpkin flour.

Sensory evaluation of gluten-free muffins

According to the ANOVA results, substitution of pumpkin flour for rice flour at 15% demonstrated the highest score for colour (Table 5). Sensory panellists perceived both GFM15 and GFM20 as ‘like slightly’. This could be attributed to the golden yellow/yellow brown colour of GFM15 and GFM20, as substitution of pumpkin flour increased the intensity of yellow colour on the crust and crumb (Table 4).

There was a significant difference ($p < 0.05$) in aroma between GFM10 and GFM0 (Table 5). However, the substitution of pumpkin flour for rice flour at 15% and above (i.e., GFM15, GFM20) showed significant reduction ($p < 0.05$) in score for aroma. This could be due to the strong ‘earthy aroma’ of the composite gluten-free muffins as the substitution level of pumpkin flour for rice flour increased from 10 to ≥15%. However, the panellists rated all the gluten-free muffins in the present work as ‘like slightly’.

The substitution of pumpkin flour for rice flour at 15% and above (i.e., GFM15, GFM20) showed significant improvement ($p < 0.05$) on the score for crumb texture (Table 5). Based on the mean score rated by the sensory panellists, it is concluded that gluten-free muffins incorporated with pumpkin flour (i.e., GFM10, GFM15, GFM20) were more favourable in terms of texture when compared to that of control. Sensory panellists could have preferred gluten-free muffins with the incorporation of pumpkin flour because of the softness in the texture of these muffins. This is in agreement with the hardness of these muffins measured using the texture analyser (Table 3).

For the crumb moistness attribute, no significant difference ($p > 0.05$) was observed among the four types of muffin produced (Table 5). This finding could be supported by the fact that the moisture content of these muffins was not significantly different ($p > 0.05$) (Table 2). The substitution of pumpkin flour for rice flour in gluten-free muffins (i.e., GFM10, GFM15, GFM20) did not significantly alter ($p > 0.05$) the sweetness of these muffins (Table 5). According to Rakcejeva *et al*. (2011), pumpkin flour has abundance of reducing sugars that could contribute to the sweet taste of the supplemented products. However, in the present work, the substitution of pumpkin flour for rice flour up to 20% was rated as ‘like slightly’ by the panellists.

The overall acceptability of all gluten-free muffins prepared was not significantly different ($p > 0.05$) among each other (Table 5). This indicates that increasing levels of pumpkin flour substitution for rice flour did not significantly change ($p > 0.05$) the overall acceptability of these muffins. In addition, all gluten-free muffins in the present work were considered acceptable by the sensory panellists, since all the muffins received scores of higher than 4 (Lazaridou *et al*., 2007).

Table 5. Sensory evaluation of gluten-free muffins formulated with various levels of pumpkin flour.

Sensory Attributes	Types of muffin[1]			
	GFM0	GFM10	GFM15	GFM20
Colour	$4.53^{a} \pm 1.80$	$4.97^{ab} \pm 1.40$	$5.53^{b} \pm 1.04$	$5.27^{ab} \pm 1.23$
Aroma	$4.67^{a} \pm 1.56$	$5.53^{b} \pm 1.01$	$5.23^{ab} \pm 1.42$	$5.27^{ab} \pm 1.23$
Crumb texture	$4.40^{a} \pm 1.49$	$5.07^{ab} \pm 1.11$	$5.23^{b} \pm 1.43$	$5.23^{b} \pm 1.63$
Crumb moistness	$4.47^{a} \pm 1.72$	$5.07^{a} \pm 1.08$	$5.03^{a} \pm 1.33$	$5.00^{a} \pm 1.41$
Sweetness	$4.90^{a} \pm 1.54$	$5.27^{a} \pm 1.39$	$4.83^{a} \pm 1.64$	$5.43^{a} \pm 1.48$
Overall acceptability	$4.73^{a} \pm 1.36$	$5.10^{a} \pm 1.21$	$5.23^{a} \pm 1.28$	$5.10^{a} \pm 1.65$

Data are mean ± standard deviation ($n = 3$). Values with different superscript letters within a row are significantly different ($p < 0.05$). [1]GFM0 (control), GFM10, GFM15 and GFM20 represent gluten-free muffin made from pumpkin flour substituted for rice flour at 0, 10, 15 and 20%, respectively.

Conclusion

The present work revealed that pumpkin flour significantly reduced ($p < 0.05$) the water activity in all composite gluten-free muffins. Gluten-free muffins prepared with partial substitution of pumpkin flour for rice flour were found to have enhanced the textural properties (i.e., softness and springiness), while maintaining the volume and specific volume of the muffin. On the basis of the colour of the muffins, all composite gluten-free muffins showed more attractive golden yellow colour of crust and crumb than that of control. All prepared muffins were acceptable by the sensory panellists. The present work provides valuable information to food technologists or rice manufacturers to explore better utilisation and promote the consumption of pumpkin and rice, especially low-quality rice, i.e. crushed rice. The approach demonstrated in the present work could also serve as a stepping stone to the production of other gluten-free bakery products such as cake and bread.

Acknowledgement

The authors gratefully acknowledge the Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin (UniSZA), Besut Campus for providing the facilities to conduct the present work.

References

Abdullah, M. Z. 2008. Quality evaluation of bakery products. In Sun, D.-W. (Ed). Computer Vision Technology for Food Quality Evaluation, p. 481–522. United States: Academic Press.

American Association of Cereal Chemists (AACC). 2000. Approved Methods of AACC. 10th Ed. Minnesota: AACC.

Association of Official Analytical Chemists (AOAC). 1995. Official Methods of Analysis. 16th Ed. Washington: AOAC.

Baker, M. G., Hudson, H., Floes, L., Bhaduri, S., Ghatak, R. and Navder, K. P. 2013. Physical, textural and sensory properties of gluten-free muffin prepared using quinoa flour as a replacement of rice flour. Journal of the Academy of Nutrition and Dietetics 113(9): A60.

Bhat, M. A. and Bhat, A. 2013. Study on physico-chemical characteristics of pumpkin blended cake. Journal of Food Processing and Technology 4(9): 262.

Bradley, R. L. 1998. Moisture and total solids. In Nielsen, S. S. (Ed). Food Analysis (2nd Ed), p. 119-139. USA: Aspen.

Codex Standard. 2018. CODEX STAN 175-1989 Standard for Soy Protein Products. Retrieved on March 19, 2018 from FAO website: www.fao.org/input/download/standards/325/CXS_175e.pdf

Deshmukh, Y., Sharma, H. K. and Kumar, N. 2017. Modeling of physicochemical and functional parameters of pumpkin (Cucurbita pepo) powder using response surface methodology. International Food Research Journal 24(5): 2071–2081.

Gallagher, E., Gormley, T. R. and Arendt, E. K. 2003. Crust and crumb characteristics of gluten-free bread. Journal of Food Engineering 56(2-3): 153–161.

González-Mateo, S., González-Sanjosé, M. L. and Muñiz, P. 2009. Presence of Maillard products in Spanish muffins and evaluation of colour and antioxidant potential. Food and Chemical Toxicology 47(11): 2798–2805.

Gujral, H. S., Guardiola, I., Carbonell, J. V. and Rosell, C. M. 2003. Effect of cyclodextrin glycosyl transferase on dough rheology and bread quality from rice flour. Journal of Agriculture and Food Chemistry 51(13): 3814–3818.

Ho, L. H., Abdul Aziz, N. A. and Azahari, B. 2013. Physico-chemical characteristics and sensory evaluation of wheat bread partially substituted with banana (Musa acuminata × balbisiana cv. Awak) pseudo-stem flour. Food Chemistry 139(1-4): 532–539.

Itthivadhanapong, P. and Sangnark, A. 2016. Effects of substitution of black glutinous rice flour for wheat flour on batter and cake properties. International Food Research Journal 23(3): 1190–1198.

Kataria, R. 2014. Proximate nutritional evaluation of maize and rice – gluten free cereal. IOSR Journal of Nursing and Health Science 3(2): 01–06.

Lazaridou, A., Duta, D., Papageorgiou, M., Belc, N. and Biliaderis, C. G. 2007. Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. Journal of Food Engineering 79(3): 1033–1047.

Maghaydah, S., Abdul-Hussain, S., Ajo, R., Tawalbeh, Y. and Alsaydali, O. 2013. Utilization of different hydrocolloid combinations on gluten-free bread making. Food and Nutrition Sciences 4(5): 496–502.

Matos, M. E, Sanz, T. and Rosell, C. M. 2014. Establishing the function of proteins on the rheological and quality properties of rice based gluten-free muffins. Food Hydrocolloids 35: 150–158.

Montaño, M. N. E., Bonifacio, R. S. and Rumbaoa, R. G. O. 1999. Proximate analysis of the flour and starch from Enhalus acoroides (L.f.) Royle seeds. Aquatic Botany 65(1-4): 321–325.

Ng, K., Bhaduri, S., Ghatak, R. and Navder, K. P. 2012. Effect of banana flour on the physical, textural and sensory characteristics of gluten-free muffins. Journal of the Academy of Nutrition and Dietetics 112(9): A58.

Nilufer-Erdil, D., Serventi, L., Boyacioglu, D. and Vodovotz, Y. 2012. Effect of soy milk powder addition on staling of soy bread. Food Chemistry 131(4): 1132–1139.

Noor Aziah, A. A. and Komathi, C. A. 2009. Physicochemical and functional properties of peeled and unpeeled pumpkin flour. Journal of Food Science 74(7): S328–333.

Nurul Ain, O., Marina, A. M. and Sakinah, H. 2016. The effect of avocado puree as fat replacer on the physical quality of muffin. Malaysian Applied Biology 45(2): 11–16.

Pongjanta, J., Naulbunrang, A., Kawngdang, S., Manon, T. and Thepjaikat, T. 2006. Utilization of pumpkin powder in bakery products. Songklanakarin Journal of Science and Technology 28(Suppl. 1): 71–79.

Ptitchkina, N. M., Novokreschonovaa, L. V., Piskunova, G. V. and Morris, E. R. 1998. Large enhancements in loaf volume and organoleptic acceptability of wheat bread by small additions of pumpkin powder: possible role of acetylated pectin in stabilising gas-cell structure. Food Hydrocolloids 12(3): 333–337.

Rakcejeva, T., Galoburda, R., Cude, L. and Strautniece, E. 2011. Use of dried pumpkins in wheat bread production. Procedia Food Science 1: 441–447.

Rodriguez Furlán, L. T., Pérez Padilla, A. and Campderrós, M. E. 2015. Improvement of gluten-free bread properties by the incorporation of bovine plasma proteins and different saccharides into the matrix. Food Chemistry 170: 257–264.

Sciarini, L. S., Ribotta, P. D., León, A. E. and Pérez, G. T. 2010. Influence of gluten-free flours and their mixtures on batter properties and bread quality. Food and Bioprocess Technology 3(4): 557–585.

See, E. F., Wan Nadiah, W. A. and Noor Aziah, A. A. 2007. Physico-chemical and sensory evaluation of breads supplemented with pumpkin flour. ASEAN Food Journal 14(2): 123–130.

Smith, J. P. and Simpson, B. K. 1995. Modified atmosphere packaging of bakery and pasta products. In Faber, J. and Dodds, K. L. (Eds). Principles of modified-atmosphere and sous vide product packaging, p. 207–242. United States: Technomic Publishing Company.

Tess, M., Bhaduri, S., Ghatak, R. and Navder, K. P. 2015. Physical, textural and sensory characteristics of gluten-free muffins prepared with teff flour (*Eragrostistef* (ZUCC) *Trotter*). Journal of Food Processing and Technology 6(9): 490.

Watts, B. M., Ylimaki G. L., Jeffery, L. E and Elias, L. G. 1989. Basic sensory methods for food evaluation. Canada: International Development Research Centre.

Wongsagonsup, R., Kittisuban, P., Yaowalak, A. and Suphantharika, M. 2015. Physical and sensory qualities of composite wheat-pumpkin flour bread with addition of hydrocolloids. International Food Research Journal 22(2): 745–752.