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Rice bran wax shortening process for application in biscuit sticks

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Abstract

The objective of the present work was to investigate the use of rice bran wax shortening for application in biscuit sticks made from rice bran flour. The biscuit sticks were studied in terms of physical, chemical, and sensory characteristics, as well as consumer acceptance. Rice bran wax shortening was prepared by rice bran oil at 60, 70, and 80% and rice bran wax at 6, 8, and 10%. The concentration of 60% rice bran oil and 10% rice bran wax produced the highest quality shortening with respect to emulsion's stability, viscosity, and texture. Rice bran flour was used at concentrations of 0, 10, 20, and 30%. Rice bran wax shortening was used at concentrations of 0, 20, 50, and 100%. Increasing the rice bran flour significantly increased the dietary fibre content of the biscuit sticks ($p \leq 0.05$). Increasing the rice bran shortening significantly decreased the saturated fatty acid contents of the biscuit sticks ($p \leq 0.05$). Increasing the rice bran flour and decreasing the rice bran shortening significantly increased roughness, density, brownness, and hardness of the biscuit sticks ($p \leq 0.05$). Consumers accepted biscuit sticks made from 10% rice bran flour and 100% rice bran wax shortening.

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Introduction

Biscuits are ready-to-eat bakery products widely consumed as snack foods in many countries (Boobier *et al*., 2006). Biscuits are produced with the use of fat, which is semi-solid at room temperature; thus, biscuit products contain in excess of 20% fat content (Nisbett *et al*., 1986). Biscuits usually contain high levels of easily digested starch, sugar, and butter, and low levels of dietary fibre (Klunklin and Savage, 2018). Due to the low nutritional value and high fat content in biscuits, there is pressure on producers to decrease the fat content (Boobier *et al*., 2006). Bakery shortening is commonly used in baked and fried products. Hydrogenation is the process by which hydrogen is added to triglycerides, thus changing unsaturated fatty acids to saturated fatty acids. When the process of partial hydrogenation is used, trans fatty acids are formed. Shortening is the product of the hydrogenation of vegetable oils which contain about 20 - 40% trans fatty acids (Hunter, 2005). Many studies demonstrate that dietary saturated fatty acids and cholesterols are major factors causing hyperlipidaemia (Kennedy *et al*., 2010). Trans fatty acids have been shown to increase the level of low-density lipoprotein cholesterol (LDL-C) and decrease the level of high-density lipoproteins cholesterol (HDL-C), thereby increasing the risk of cardiovascular disease (Mensink *et al*., 2003). Trans fatty acids have also been associated with an increased risk of breast cancer, colon cancer, diabetes mellitus, obesity, and allergies (Dhaka *et al*., 2011).

Rice bran is a by-product of rice processing which can be classified as either full fat or defatted rice bran (Issara and Rawdkuen, 2016). Rice bran contains many important nutrients beneficial to the body such as antioxidants, dietary fibres, essential unsaturated fatty acids, and essential amino acids (Sharma *et al*., 2015; Rahim *et al*., 2015). Tocotrienols and oryzanol are antioxidants that can be found in rice bran (Mishra and Chandra, 2012). Rice bran contains 10 - 23% oil, of which 3 - 9% is wax, and a very large amount of insoluble dietary fibres (Marlene *et al*., 2005; Gul *et al*., 2015; Hussein and Al-Okbi, 2015). Rice bran oil is generally considered to be one of the highest quality vegetable oils in terms of its cooking quality, shelf life, and fatty acid composition. Rice bran contains 7 - 13% soluble

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fibre, with the rest being insoluble fibre (Anderson *et al*., 1990). Given the nutritional value of rice bran, many studies have explored its use in the food industry (Ghufan *et al*., 2009; Al-Okbi *et al*., 2014; Gul *et al*., 2015; Sharma *et al*., 2015; Issara and Rawdkuen, 2016). Defatted rice bran is reported to contain 34.9% dietary fibre, 15.6% protein, 11.3% moisture, 9.86% ash, and 2.2% fat (Mishra and Chandra, 2012). Waxes consist of wax esters, glycerol esters, long-chain fatty acids and alcohols, aldehydes, and ketones (Doan *et al*., 2018). Rice bran waxes are obtained from the rice bran oil refining process. Generally, rice bran waxes contain 0.4 - 1.5% crude wax (Vali *et al*., 2005). The melting point of wax is 80 - 83°C (Vali *et al*., 2005).

To reduce saturated and trans fatty acids in food products, alternative fats have been the subject of recent studies. Oleogelation is a concept in which oil is transformed into a three-dimensional gel network using one or more oleogelators (Doan *et al*., 2018). Oleogels substitute saturated fats with unsaturated oils, thus resulting in an assembly of networks or gels (Co and Marangoni, 2012; Patel and Dewettinck, 2016). Plant waxes, including rice bran, candelilla, carnauba, sunflower, and sugarcane wax are the most efficient crystalline oleogelators, due to a well-formed network of crystallisation with strong oil-binding properties at low wax concentrations, which ranges between 1 - 4% per weight, or at the lowest concentration of 0.5% per weight (Abdallah *et al*., 2000; Blake *et al*., 2014). Crystallisation of waxes is based on a high melting point, low polarity, and long chain length (Mukkamala and Weiss, 1996). There have been many studies on oleogel properties produced from different plant waxes (Jeongtaek *et al*., 2017). As mentioned in various previous studues, there are many benefits of rice bran, rice bran oil, and rice bran wax, while commercial shortening in food and bakery products are harmful to the human body. Thus, investigation into oleogels made from rice bran oil and wax, and the application of oleogels in food and bakery products has become more frequently conducted. Wax-based oleogels have potential to be the structural fat for margarine or shortening replacement in bakery products due to their good functional properties. Bakers are well aware of these issues, and they have shown some interest in developing biscuits, which can be regarded as a functional food containing less butter. Recently, products with high protein and fibre contents are more commonly chosen by consumers in order to combat diseases such as diabetes and obesity.

The main objective of the present work was therefore to use rice bran flour and wax shortening processes to produce biscuit sticks and assessed in terms of the physical, chemical, sensory characteristics, and consequent consumer acceptance. It was hypothesised that rice bran flour and wax shortening can be used in the production of biscuit sticks. The present work's aims were to: (1) produce and evaluate rice bran shortening in terms of stability, viscosity, and texture; (2) characterise physical and chemical properties of biscuit sticks made from rice bran flour and rice bran shortening; and (3) evaluate the sensory acceptability of the resultant biscuit sticks. The information obtained can be used for application in the manufacture of either bakery products or healthy snack food products with desirable sensory characteristics.

Materials and methods

Materials

Crude rice bran wax (KD6 variety) and rice bran flour (KDML105) were purchased from Thailand.

Pure rice bran wax preparation

Pure rice bran wax was prepared by mixing hexane with crude rice bran wax at a concentration ratio of 1:5 (w/v), and then melting it at 60°C, followed by cooling at 5°C for 2 h. Centrifugation clearly separated wax from the solvent. After that, the wax was cleaned with isopropanol at a concentration ratio of 1:5 (w/v). The wax was dried by evaporation at 80 - 90°C with stirring for 15 min. The wax composition was analysed by gas liquid chromatography. The wax mainly composed of saturated fatty alcohols of C24 and C30, saturated fatty acids of C16 and C26, and *n*-alkanes of C21 and C29. Finally, the pure rice bran wax was placed at room temperature to let it completely dry.

Oleogel preparation

Oleogels were prepared by adding accurately weighed rice bran wax at different concentrations (6, 8, and 10%, w/w) to rice bran oil at different concentrations (60, 70, and 80%, w/w). The blended mixture was heated at 50°C for 3 min. The solution was further diluted with mixture of melted rice bran wax and oil at a ratio of 30:70, and the total volume adjusted to 100% by weight of total composition. The dispersions were heated with agitation at 90°C for 5 min until completely dissolved, and then held at the same temperature. The clear mixture was then cooled down at room temperature, thus resulting in the formation of rice bran wax oleogels.

Rice bran shortening (emulsion) preparation

The rice bran shortening (emulsion) was prepared by water-in-oil (W/O) emulsion. The W/O emulsions were prepared with 40% water content by weight of the oleogel. The oleogel was melted with water at 85°C for 15 min, and cooled to room temperature. Then lecithin, the emulsifier agent, was mixed in at a concentration of 0.16%. The solution was thoroughly blended with a blender at a speed of 60 rpm for 45 min. The rice bran shortening was stored at 5°C until further experiments.

Rice bran shortening stability

After placed at room temperature for 30 min, the rice bran shortening (emulsion) was centrifuged at a speed of 3,000 rpm for 30 min, then water and oil separation and the percentage of rice bran shortening stability were tested. Emulsion stability was adapted from Pandolsook and Kupongsak (2017).

Rice bran shortening viscosity

The temperature of the samples was limited to 25 ± 1°C. The viscosity of the oleogels was measured with a Brookfiled HA device by means of a DIN-87 spindle.

Rice bran shortening texture

The hardness of the rice bran shortening was analysed with a texture analyser TX.AT plus (Micro Stable System, UK), by means of penetration testing. A cylindrical tip with a diameter of 1 cm was used and dipped at 5 mm into a sample at a speed of 1 mm/s. Rice bran shortening at 25°C was analysed in their containers (3.5 cm diameter with rice bran shortening depth of 2.5 cm). The sample was compressed at 1.0 mm/s. Since a ratio of 60% rice bran oil and 10% rice bran wax was the most suitable to achieve ideal stability, viscosity, and hardness of rice bran shortening, rice bran shortening with this ratio was used to prepare biscuit sticks.

Potential application of rice bran flour and shortening for biscuit sticks

In biscuit stick formulation, rice bran flour was replaced for wheat flour, and rice bran shortening was replaced for commercial shortening. The rice bran flour was used in proportions of 0, 10, 20, and 30% of wheat flour (all-purpose flour), while the rice bran shortening was at 0, 20, 50, and 100% of commercial shortening, respectively. Then, 100% all-purpose flour with 28% water, 20% sweetened condensed milk, 19% commercial shortening, 4% sugar, 1% baking soda, and salt were combined and mixed. The batter was set aside for 15 min, and rolled into dough to a thickness of 2 mm. The dough was cut into pieces of 12 × 0.4 cm, and baked at 150°C for 15 min. The length of the baked product was 12 cm, and the thickness was 5 mm.

Physical properties of biscuit sticks

Instrumental analysis of the hardness and fracture force of the biscuit sticks were determined using a texture analyser TX.AT plus (Micro Stable System, UK) equipped with three-point bending. The maximum force was recorded as hardness and the peak maximum force before fracture. The measurement conditions of the test were compression mode, pre-test speed of 2.0 mm/s, trigger force of 3 × *g*, test speed of 0.5 mm/s, and test distance of 6 mm. At least ten samples were analysed for each biscuit stick.

Chemical properties of biscuit sticks

The saturated fatty acids of biscuit sticks were determined using AOAC Official Methods 996.06. A gas chromatography-flame ionisation detection (GC-FD) method was applied for direct quantitative analysis of saturated fatty acids. The amount of saturated fatty acids was calculated according to Ali *et al.* (1997) and Jeongtaek *et al*. (2017). The dietary fibre content of biscuit sticks was determined by Megazyme Total Dietary Fibre Test Kit (AACC Method 32-05 and 32-21). Protein, fat, moisture, ash, and carbohydrate contentd were determined for all biscuit formulation. Protein content was determined by the Dumas method (AOAC, 2005) through a CN-2000 elemental analyser (Leco Corp., St. Joseph, MI, USA). Protein was calculated from nitrogen using the conversion factor of 6.25. Fat content was determined using dried samples extracted with petroleum ether (BP 40-60C) for 4 h in an extracting unit Soxtec System 2055 Tecator (FOSS, Hillerød, Denmark), and gravimetrically determined. Moisture was determined by drying at 100°C (AOAC, 2005). Ash was determined by heating in a 550°C furnace for 24 h (AOAC, 2005). Carbohydrates were determined by difference.

Sensory evaluation

Sensory evaluation was conducted by 10 panellists (24 - 35 years old, 5 males and 5 females) comprising trained students from Srinakharinwirot University who performed descriptive analysis of sensory attributes. An intensive 50 h were spent on descriptive sensory panel training using a barrage of samples and sensory techniques through scaling (with a 15-point intensity scale). The panellists discussed definitions and evaluation methods. Finally, sensory attributes and their respective reference intensities were established. The panel also discussed the anchoring references for each attribute. Many baked product samples from markets were reviewed. Each sample was evaluated in a randomised complete block design. The definitions and the testing method of all descriptive terms were as follows: roughness described biscuit stick whose surfaces were clearly not smooth; brownness was the degree of the brown appearance clearly noticeable on the biscuit stick's surface; hardness described the degree of difficulty in swallowing one sample of the biscuit stick; and density was the ability of a cross-sectional structure of the sample to be forced or compressed.

Consumer acceptance

The test samples were randomly presented to each assessor. Three pieces of each sample, in a white dish coded with a 3-digit random number, were presented in monadic servings to each consumer. Biscuit sticks were evaluated for appearance, taste, odour, flavour, and texture using seven-point hedonic scales (1 = "like not at all" to 7 = "like very much"). The samples were served at room temperature (25 ± 1°C), and the evaluation was conducted under normal lighting conditions. The consumer cleansed their palates between samples with drinking water.

Statistical analysis

All experiments were conducted in duplicate. SPSS software version 17 (SPSS Inc., USA.) was used for statistical analysis. The analysis of variance (ANOVA) was used to determine the effects of factors. Duncan's new multiple range test was used to compare means ($\alpha = 0.05$). The sensory evaluation and consumer acceptance was conducted with Randomised Complete Block Designs (RCBD). The panellists and consumers were treated as blocks.

Results and discussion

Rice bran shortening (emulsion) stability

The rice bran shortening (emulsion) stability was analysed using a test for water and oil separations, and the percentage of rice bran shortening stability (Figure 1a). At a constant level of rice bran wax, the increasing rice bran oil significantly decreased ($p \leq 0.05$) the emulsion stability. The oleogels containing higher concentrations of rice bran wax were the most resistant to melting. This was due to increasing quantity of rice bran wax which presented a network of interlinked wax crystals. Using a heating process, the structure of rice bran wax crystals was shown not to change (Wijarnprecha *et al*., 2018). Samuditha *et al*. (2012) reported that the high thermal stability, crystallinity, and strength of rice bran wax organogels were the result of high melting temperatures and thin needle-shaped crystals of rice bran wax. Furthermore, in the present work, at a constant level of rice bran oil, increasing rice bran wax significantly increased ($p \leq 0.05$) the emulsion stability. This may be described as tightly packed in the rice bran wax crystal structure (Dassanayake *et al*., 2011). Therefore, in the present work, a combination of 60% rice bran oil and 10% rice bran wax yielded the highest rice bran shortening stability.

Rice bran shortening (emulsion) viscosity

The rice bran shortening (emulsion) viscosity was analysed (Figure 1b). With a constant level of rice bran wax, increasing rice bran oil significantly decreased ($p \leq 0.05$) the emulsion viscosity; however, maintaining a constant level of rice bran oil with increasing rice bran wax significantly increased the emulsion viscosity ($p \leq 0.05$). The oleogel viscosity was dependent on the content of wax used such that the oleogel containing higher percentages of wax was highly viscous (Jang *et al*., 2015). Oleogels prepared with canola oil and candelilla wax exhibited higher viscosity than shortening at 50 - 70°C; however, shortening showed the highest values of viscosity at 25°C (Jang *et al*., 2015). Samuditha *et al*. (2012) reported that increasing rice bran wax concentrations increased viscosity in rice bran wax salad oil gels. The viscosity of gels at 3% (w/w) rice bran wax was

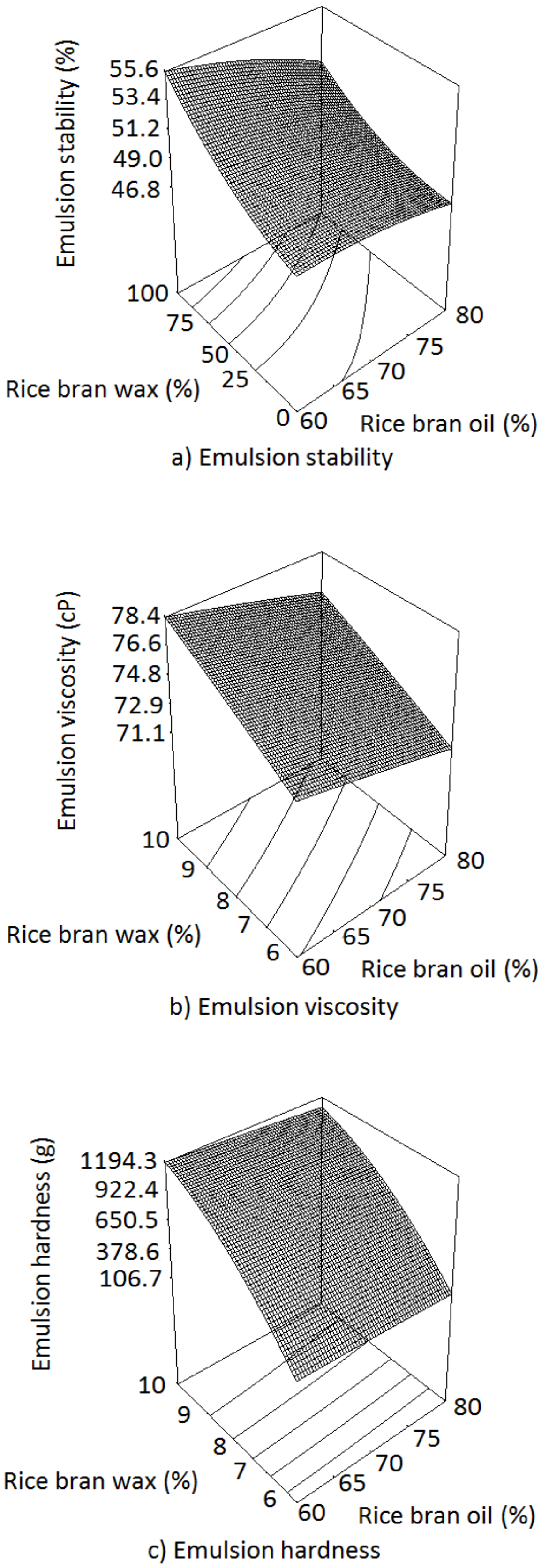


Figure 1. Comparison of rice bran oil and rice bran wax compositions with respect to emulsion's stability **(a)**, viscosity **(b)**, and hardness **(c)** of rice bran wax shortening.

found to be three times higher than at 1% (w/w) rice bran wax. Similarly, the viscosity of the same mixture at 6 and 10% (w/w) were 10 times higher than at 3% (w/w). The effect of wax concentration on hardness and viscosity was explained by size and shape of crystals. Increasing rice bran wax contributes to longer and thicker fibrous-like needle crystals which create a strong crystal network; thus, at high melting points, viscous and hard organogels are formed. Therefore, in the present work, 60% rice bran oil and 10% rice bran wax yielded the highest rice bran shortening viscosity.

Rice bran shortening (emulsion) texture

The rice bran shortening (emulsion) hardness was analysed (Figure 1c). At a constant level of rice bran wax, increasing rice bran oil significantly decreased ($p \leq 0.05$) the emulsion hardness, while at a constant level of rice bran oil, increasing rice bran wax significantly increased the emulsion hardness ($p \leq 0.05$). Sung and Lin (2017) found that increasing the ratio of beeswax significantly increased the hardness and adhesiveness of organogel ($p \leq 0.05$). This could be due to the straight-chain acids with up to 36 carbon skeletons which resulted in a strong network of gels forming during crystallisation. Gel strength increased as candelilla wax concentration increased.

Physical properties of biscuit sticks

Mechanical measurement of the texture of biscuit sticks showed (Table 1) that hardness and fracturability of those made from 30% rice bran shortening and 30% rice bran flour were significantly higher. Biscuits made from 100% commercial shortening and 10% rice bran flour were significantly lower than those made from 50% rice bran shortening and 20% rice bran flour. Commercial shortening lubricates the internal structure of intermediates to allow greater expansion during proofing and baking, thus making the texture of finished product tender. It modifies the visual and tactile texture of crust in the desirable ways. Textural characteristics of biscuits are an important factor contributing to their quality. Hardness is one of the key factors which determines the texture properties of biscuits, and measured as the peak force needed to penetrate the biscuits. In the present work, this significantly increased ($p \leq 0.05$) when different levels of rice bran flour were incorporated in the biscuits. A higher level of fibre in the biscuit formulation made from rice bran flour absorbed more water; therefore, the biscuit mix had less water left in the mixture which led to a condensed texture after baking because of full gelatinisation (Giuberti *et al*., 2017). Chung *et al*. (2014) also reported that biscuits made from different types of rice flour had altered hardness.

Table 1. Physical properties of biscuit sticks.

Commercial shortening: Rice bran shortening	Wheat flour: Rice flour	Hardness (kg)	Fracture force (kg)
100:0	90:10	2.59 ± 1.45^{c}	2.18 ± 1.03^{c}
50:50	80:20	4.86 ± 0.78^{b}	4.05 ± 1.78^{b}
70:30	70:30	6.59 ± 1.45^{a}	6.18 ± 1.03^{a}

Means followed by different lowercase superscripts in a column are significantly different ($p \leq 0.05$).

Chemical properties of biscuit sticks

Chemical compositions of biscuit sticks are shown in Table 2. Nutritional analyses were carried out in order to evaluate the proximate composition of the different ratios of shortening and flour assessed in the present work. Results showed significant differences among rice bran flour ratios on ash, protein moisture, and carbohydrate (Table 2). Higher rice bran flour content showed significant ($p \leq 0.05$) higher levels of ash regardless of the wheat flour. It is known that high rice flour content contains higher levels of minerals than wheat.

Protein is the second most abundant component in wheat starch. High wheat content also showed significantly higher protein level than lower wheat content in biscuits. Torbica *et al*. (2012) also observed a decrease in the protein contents with corresponding increases in the proportion of rice flour substituted for wheat flour in the biscuits.

Moisture content of biscuits increased linearly ($p \leq 0.05$) with the increased concentration of rice bran flour in the biscuit mix, therefore, biscuit sticks made from 30% rice bran flour had the highest moisture content due to the high fibre content and swelling power of rice bran flour. Water content in food products affects the texture and consumers' acceptability of the final quality (Sharma *et al*., 2016; Klunklin and Savage, 2018). In the present work, the level of moisture was within the range of 10% for baked products (cake, biscuit, and bread) to prevent spoilage and extend shelf life (Okaka and Potter, 1977).

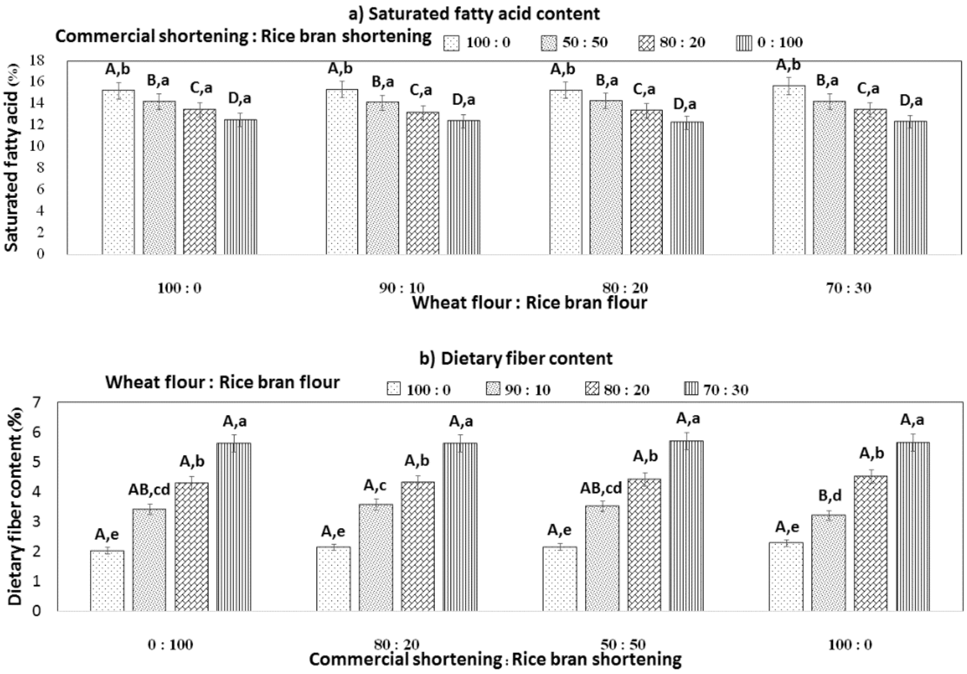
Table 2. Chemical properties of biscuit sticks.

Commercial shortening:Rice bran shortening	Wheat flour:Rice flour	Ash (%)	Fat^{ns} (%)	Moisture (%)	Protein (%)	Carbohydrate (%)
100:0	100:0	3.05 ± 0.02^{a}	28.46 ± 0.56	10.13 ± 0.13^{c}	11.78 ± 0.04^{a}	46.58 ± 0.17^{c}
50:50	100:0	3.01 ± 0.01^{a}	28.41 ± 0.42	10.11 ± 0.11^{c}	11.79 ± 0.03^{a}	46.68 ± 0.11^{c}
80:20	100:0	3.04 ± 0.02^{a}	28.38 ± 0.31	10.12 ± 0.12^{c}	11.77 ± 0.02^{a}	46.69 ± 0.15^{c}
0:100	100:0	3.02 ± 0.02^{a}	28.15 ± 0.83	10.12 ± 0.12^{c}	11.76 ± 0.02^{a}	46.95 ± 0.12^{c}
100:0	90:10	2.21 ± 0.00^{b}	27.98 ± 0.56	10.74 ± 0.56^{bc}	10.72 ± 0.04^{b}	48.35 ± 0.77^{b}
50:50	90:10	2.11 ± 0.01^{b}	27.97 ± 0.55	10.73 ± 0.45^{bc}	10.71 ± 0.01^{b}	48.48 ± 0.72^{b}
80:20	90:10	2.23 ± 0.01^{b}	27.99 ± 0.42	10.76 ± 0.55^{bc}	10.72 ± 0.03^{b}	48.30 ± 0.78^{b}
0:100	90:10	2.25 ± 0.02^{b}	27.96 ± 0.53	10.73 ± 0.54^{bc}	10.71 ± 0.02^{b}	48.35 ± 0.72^{b}
100:0	80:20	1.98 ± 0.02^{c}	28.68 ± 0.51	10.98 ± 0.52^{ab}	9.89 ± 0.01^{c}	48.47 ± 0.02^{b}
50:50	80:20	1.99 ± 0.01^{c}	28.65 ± 0.22	10.97 ± 0.53^{ab}	9.88 ± 0.02^{c}	48.51 ± 0.02^{b}
80:20	80:20	1.97 ± 0.01^{c}	28.67 ± 0.52	10.96 ± 0.43^{ab}	9.86 ± 0.01^{c}	48.54 ± 0.02^{b}
0:100	80:20	1.99 ± 0.03^{c}	28.67 ± 0.42	10.98 ± 0.52^{ab}	9.88 ± 0.02^{c}	48.48 ± 0.02^{b}
100:0	70:30	1.35 ± 0.00^{d}	28.07 ± 0.51	11.01 ± 0.12^{a}	7.63 ± 0.00^{d}	51.94 ± 0.13^{a}
50:50	70:30	1.34 ± 0.00^{d}	28.05 ± 0.41	11.02 ± 0.12^{a}	7.62 ± 0.00^{d}	51.97 ± 0.13^{a}
80:20	70:30	1.36 ± 0.01^{d}	28.06 ± 0.31	11.01 ± 0.11^{a}	7.63 ± 0.01^{d}	51.94 ± 0.13^{a}
0:100	70:30	1.33 ± 0.02^{d}	28.05 ± 0.52	11.02 ± 0.11^{a}	7.64 ± 0.02^{d}	51.96 ± 0.13^{a}

Means followed by different lowercase superscripts in a column are significantly different ($p \leq 0.05$).
^{ns}non-significant difference among sample ($p > 0.05$).

Fat content of biscuit sticks

All biscuit sticks formulated in the present work contained high fat content (28%) from shortening. Commercial shortening is rich in saturated fatty acids (Klunklin and Savage, 2018). Figures 2a and 2c show the saturated fatty acid contents of the biscuit sticks. With a constant amount of rice bran flour, increasing rice bran shortening significantly decreased saturated fatty acid content ($p \leq 0.05$). This was consistent with the study of Jeongtaek *et al*. (2017) which demonstrated that the ratios of saturated fatty acid in muffins prepared with oleogels significantly decreased from 2.81 to 0.41. In addition, unsaturated fatty acids in oleogel cookies significantly increased to 92% as compared to shortening cookies at 47.2% (Jang *et al*., 2015). Due to the high unsaturated fatty acid and low saturated fatty acid contents found in oleogel from natural wax, significant decrease in saturated fatty acid content in baked products was also reported when shortening was replaced with oleogels (Mert and Demirkesen, 2016). In the present work, while at a constant level of rice bran shortening, increasing rice bran flour provided saturated fatty acid content that was not significantly different ($p > 0.05$). Perzybylski and Mag (2002) studied the composition, properties, and uses of vegetable oils in food technology, and reported similar results. Rice bran oil was found to have a much higher content of linoleic acid as compared to that of bakery shortening.



A-D represent significant differences among samples (p≤0.05) with varied shortening and rice bran wax shortening variables.
a-e represent significant differences among samples (p≤0.05) when varying only wheat flour and rice bran flour variables.

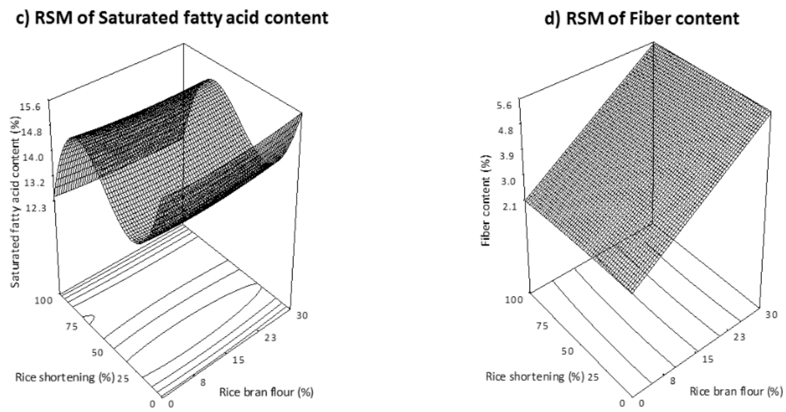


Figure 2. Saturated fatty acid **(a)**, dietary fibre content **(b)**, and response surface of saturated fatty acid **(c)** and dietary fibre **(d)** in biscuit sticks.

Dietary fibre content of biscuit sticks

Figures 2b and 2d show the dietary fibre contents of the biscuit sticks. At a constant level of rice bran shortening, increasing rice bran flour significantly increased dietary fibre content ($p \leq 0.05$), while at a constant amount of rice bran flour, increasing rice bran shortening yielded no significant difference in dietary fibre ($p > 0.05$). Approximately 27 - 30.32% dietary fibres such as cellulose, hemicellulose, alpha-glucan, and beta-glucan were found in rice bran (Gul *et al*., 2015; Hussein and Al-Okbi, 2015). In addition, similar findings indicate that the dietary fibre content of defatted rice bran cookies increased with the supplementation of rice bran from 0.16 to 9.5% (Mishra and Chandra, 2012). The dietary fibre content of cookies increased in proportion to rice bran content. Therefore, the increase in dietary fibre content of biscuit sticks assessed in the present work could be attributed to the rich dietary fibre content from rice bran (Perez *et al*., 2013; Jang *et al*., 2015).

Sensory evaluation of biscuit sticks

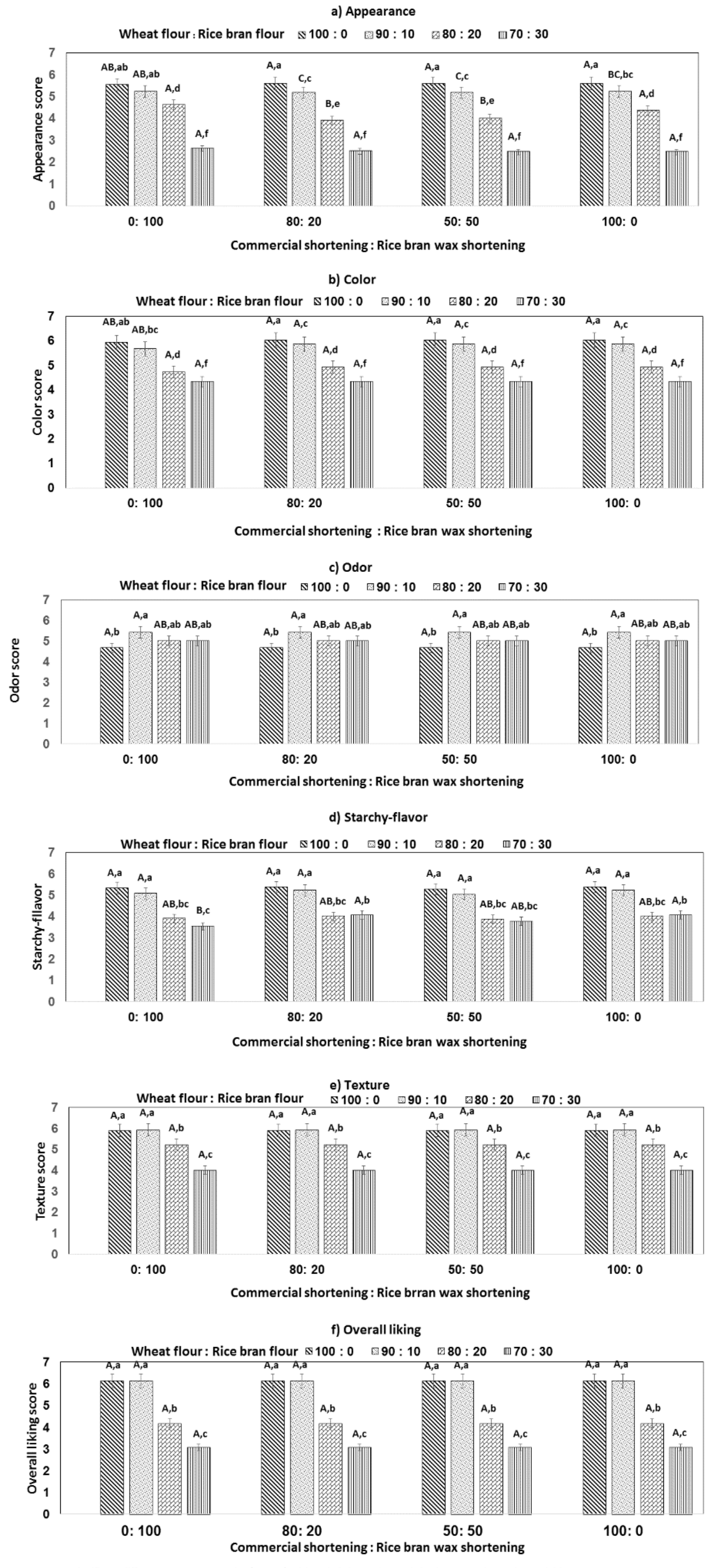
A lexicon composed of 11 sensory attributes with definitions was developed by the panellists. Sensory characteristics were divided into two main categories: appearance and texture. Increasing rice bran flour and shortening contents resulted in increased roughness, density, brownness, and hardness ($p \leq 0.05$). As presented in Figure 3, the control samples were the least dense while 50% rice bran flour yielded the most dense biscuit sticks. Wheat flour is able to form a strong gluten network structure which then entraps air in pockets within the structure, as rice bran flour is considered to have high dietary fibre content. It is believed that the fibre prevents the complete formation of the gluten network, thus resulting in decreased gases in the structure hence leading to greater density of texture (Mishra and Chandra, 2012). Jeongtaek *et al*. (2017) stated that the replacement of oleogels at quantities greater than 50% provided a poor air-holding capacity, while the use of oleogels of more than 25% decreased the specific volume of products after baking. The ineffectiveness of air cells holding in the batters with increasing oleogels produced biscuits with harder texture. The addition of dietary fibre from oats in cakes also increased the dietary fibre, thus resulting in significantly more dense cakes (Majzoobi *et al*., 2015). Similarly, the effect of dietary fibre on the qualities of bread observed that the addition of more than 7% dietary fibre resulted in decreased bread volume due to the reduction in gluten (Pomeranz, 1977). Moreover, the effect of wheat and rice bran on the properties of bread led to increase hardness and crispness (Ozkaya *et al*., 2018). The relationship of physical characteristics and sensory evaluation was presented in the present work. As the levels of rice flour increased and rice bran shortening decreased, the biscuit sticks became much harder and with high fracturability.

Jang *et al*. (2015) reported that commercial bakery shortening had significantly higher solid fat content than oleogels prepared with hazelnut oil and waxes. Solid fat is essential for the development of air cells in the structure of baked goods, such that the lowest thickness was found in cookies containing commercial bakery shortening as compared to cookies made from oleogel. Also, commercial bakery cookies with shortening showed significantly less compactness than oleogel cookies, thus indicating better air bubbling inside the cookies. This can thus provide more brittleness and fracturability in products using commercial shortening because commercial bakery shortening aerate better than oleogels (Jacob and Leelavathi, 2007; Yilmaz and Ogutcu, 2015). Many previous studies have found that less aeration was related to greater hardness of baked goods. Since fine triglyceride crystals and beta-polymorphs have been observed in the wax oleogels, this crystal morphology seems not to support aeration in cookie dough (Jacob and Leelavathi, 2007; Sudha *et al*., 2007; Marangoni, 2012).

On the other hand, brownness (browning of bakery products) might be dependent on caramelisation, dextrinisation of starch, or non-enzymatic reactions (Maillard reaction) between reducing sugar molecules and lysine protein, such that increasing rice bran results in darker brown baked goods (Sudha *et al*., 2007; Mishra and Chandra, 2012).

Consumer acceptance of biscuit sticks

Consumer acceptance of the biscuit sticks was analysed with a 7-point hedonic scale. With a constant level of rice bran shortening, increasing rice bran flour resulted in significantly decreased ($p > 0.05$) consumer acceptance of biscuit sticks for appearances, colour, odour, flavour, texture, and overall acceptance (Figures 4 and 5). Increasing the



A-D represent significant differences among samples (p≤0.05) with varied shortening and rice bran wax shortening variables.
a-e represent significant differences among samples (p≤0.05) when varying only wheat flour and rice bran flour variables.

Figure 3. Sensory characteristics of biscuit sticks made from rice bran flour and rice bran wax shortening: appearance **(a)**, colour **(b)**, odour **(c)**, starchy-flavour **(d)**, texture **(e)**, and overall liking **(f)**.

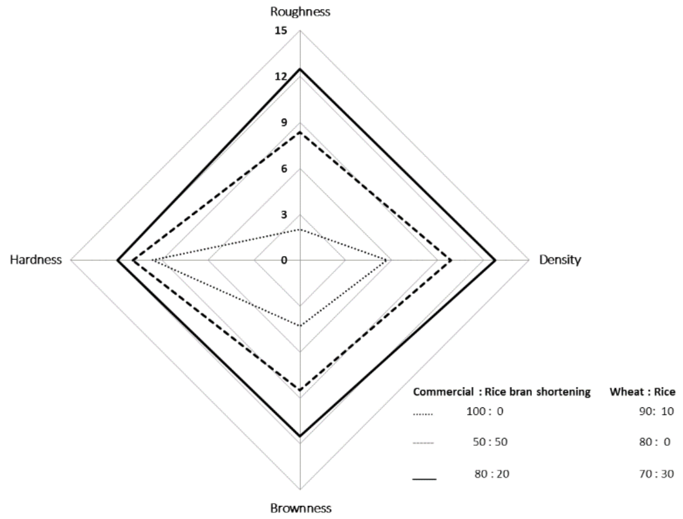


Figure 4. The potential application of rice bran flour and rice bran wax shortening for consumer acceptance of biscuit sticks.

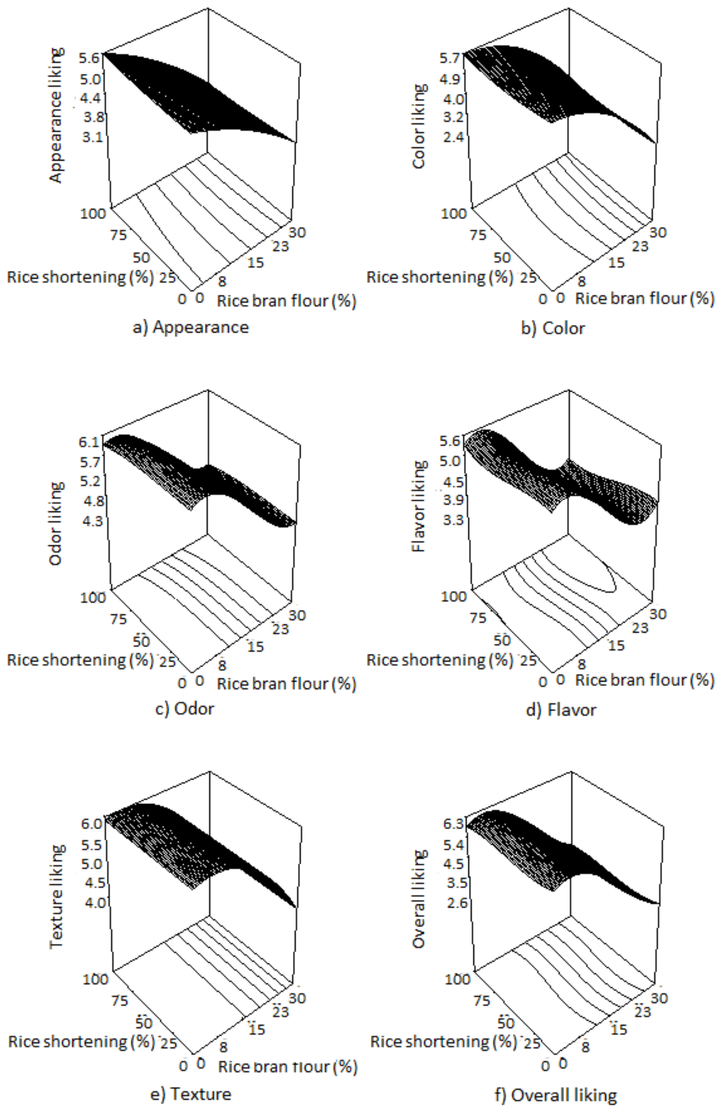


Figure 5. Response surface from consumer acceptance of biscuit sticks: appearance **(a)**, colour **(b)**, odour **(c)**, flavour **(d)**, texture **(e)**, and overall liking **(f)**.

rice bran shortening while the rice bran flour remaining constant resulted in no significant difference in consumer acceptance of appearance, colour, odour, flavour, texture, and overall acceptance ($p > 0.05$). Neither increasing rice bran flour nor increasing the quantity of rice bran shortening resulted in significant differences in consumer acceptance of the biscuit sticks ($p > 0.05$). Sung and Lin (2017) indicated that the appearance, odour, flavour, and overall acceptability of cookies made with shortening was higher than cookies made with organogels. The darkness of the biscuit was directly related to increased rice bran flour. This agrees with a previous study in which the addition of rice bran fibre caused darkening of the product resulting from the fibre (Hu *et al*., 2009). The yellow brown colour of biscuits is generated from the caramelisation of the sugar in the recipe or a Maillard reaction during baking at a high temperature (Sharma *et al.*, 2016). Thus, the high wheat flour biscuits contained the highest protein content with liking of the appearance and colour at a high score. The starchy-flavour scores of blended flour biscuits significantly decreased ($p \leq 0.05$) along with increased rice bran flour substitution levels. A few studies have observed the influence of rice flour substitution on the sensory acceptance of biscuits. Mancebo *et al*. (2016) prepared biscuits from different ratios of white rice flour mixed with protein, and showed good overall acceptability scores. Rice protein cannot generate a viscoelastic network like gluten in wheat, which retains carbon dioxide during biscuit dough fermentation. So, the addition of rice to a biscuit mix can have a significant effect on the textural qualities of the baked biscuits (Klunklin and Savage, 2018). This indicates that at substitution levels of more than 30%, the preference on the biscuits in terms of overall acceptability significantly decreased. Therefore, the present work demonstrated and reported the suitable level for producing acceptable biscuit sticks of 10% rice bran flour and 100% rice bran shortening.

Conclusion

The rice bran shortenings were made from rice bran oil at 60, 70, and 80% with rice bran wax at 6, 8, and 10%. The 60% rice bran oil and 10% rice bran wax produced the highest quality shortening with respect to emulsion stability, viscosity, and texture (hardness). The best quality of rice bran shortening produced was used in the production of the biscuit sticks. With rice bran shortening remaining constant, increasing rice bran flour significantly increased the dietary fibre of biscuit sticks ($p \leq 0.05$). While with rice bran flour remaining constant, increasing rice bran shortening significantly decreased saturated fatty acid contents of biscuit sticks ($p \leq 0.05$). In addition, increasing rice bran flour and decreasing rice bran shortening resulted in significant increases in roughness, density, brownness, and hardness of biscuit sticks ($p \leq 0.05$). Consumers accepted biscuit sticks made from 10% rice bran flour and 100% rice bran shortening. With the desirable properties, rice bran shortening can be considered as an alternative for food producers to produce trans-fat-free food products. Possible future research would be to continue studying shortening in different products. The model developed in the present work can be used to evaluate the desirable characteristics of product.

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