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Effects of partial coconut flour fortification and butter reduction with pumpkin puree in rice donuts

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Abstract

Coconut flour is rich in dietary fiber and protein, is lower in calories, and has a lovely tropical aroma than rice flour. At the same time, plant-based fat replacers, such as fruit and vegetable puree, which can provide moisture, thickening properties, and lower calories than fat, are popularly used in low-fat baked products. Thus, a reduced-butter gluten-free rice donut with coconut flour has been developed for people with celiac disease. This study evaluated the effect of different coconut flour levels (0%, 10%, 20% and 30% (w/w)) for rice flour in donuts under all-butter and reduced-butter (butter/ pumpkin puree = 75/25 w/w) conditions. The experimental results were subjected to a two -way analysis of variance, and principal component analysis was used for perceptual mapping. The physical properties assessed were specific volume, firmness, *L**, *a**, and *b**, while a 9-point hedonic scale was used for sensory evaluation. Incorporating 10% to 30% coconut flour significantly decreased the specific volume but increased firmness, *L**, *a**, and *b**, in all-butter and reduced-butter conditions. Rice donuts with 10% coconut flour received higher scores for sensory perception than those made with 20% and 30% coconut flour. Replacing 25% of the butter with pumpkin puree improved some sensory attributes such as color, flavor, and texture. The optimal formulation was the rice donut fortified with 10% coconut flour in the reduced-butter condition.

1. Introduction

With a rise of 7.5% per year over the past decades, the increase in celiac disease has pressured the industry to produce gluten-free foods (King *et al*., 2020). Rice flour has been widely studied for wheat replacement in bakery products due to its bland and neutral taste, low prolamine level, and hypoallergenic nature (Omary *et al.,* 2012). It is also high in fiber and low in saturated fat and cholesterol but has a lower protein content than wheat flour. In addition, rice flour has no gluten. It does not absorb liquid and fat like wheat flour, and its poor viscoelastic properties cause the dough to retain gas and moisture, leading to undesirable final baked products (Guimarães *et al*., 2019).

Today, bakery products that are low in fat and high in nutrients are still the first choice for consumers aware of the adverse effects of fat—obesity, cardiovascular disease, diabetes, and some cancers (Abdullah *et al*., 2010). Coconut flour is a gluten replacer with a higher fiber and protein content than wheat flour, showing good water-absorbing ability during baking. The dietary fiber content of coconut flour is about 60 g/100 g sample, 56% insoluble and 4% soluble fiber (Trinidad *et al*., 2006). The flour also contains healthy medium-chain triglycerides containing lauric acid and monolaurin, which may reduce cardiovascular risk and provide antiviral and antibacterial properties in the body. It also helps regulate blood sugar levels and relieve constipation (Levy, 2019). Coconut flour would be an interesting alternative for fiber enhancement instead of whole grains, nuts, seeds, and broccoli. It does not cause excess gas and bloating, negatively affecting gastrointestinal disorders, which are common celiac symptoms (Demirkesen *et al*., 2013).

The growth of plant-based fat replacer applications such as pumpkin puree, apple sauce, and prune paste, has been of interest in developing products containing less fat, which are also considered functional foods due to the high fiber increase. Pumpkin puree is a naturally sweet and creamy fat replacer with a high content of phytochemicals such as β-carotene and antioxidants. It is usually used to improve baked products' textural and rheological properties due to its high content of pectin and cellulose - a gelling and thickening agent (Kia and

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Hosseini Ghaboos, 2018). This fat replacer can provide up to 4 kcal/g, but often prepared or mixed with water, it typically provides only 1.5 to 2.5 kcal/g, thus promoting the marketing potential of bakery products (Colla *et al*., 2018).

Developing a low-fat and high-fiber rice donut which tastes just as good as the regular formulation can increase the alternatives available to celiac patients. Therefore, the present study investigated the amount of coconut flour suitable for rice flour replacement in a donut prepared with a reduced-butter formulation (butter/pumpkin puree = 75/25 w/w). The impact on quality in terms of physical properties and sensory profile was assessed and an optimal formulation was identified.

2. Materials and methods

2.1 Materials

Rice flour (New Grade®, Thai Wah Public Co., Ltd., Thailand), coconut flour (Cocowel®, Tropical Nutrition Co., Ltd., Thailand) were purchased from a supermarket. Ripe pumpkin (*Cucurbita moschata* Decne) was used. Other ingredients included unsalted butter, low-fat milk, whole egg, leavening agent, salt and sugar.

2.2 Preparation of pumpkin puree

Ripe pumpkin fruit was halved, deseeded, cut into small cubes and washed with tap water. The cut pumpkin was steamed for 30 mins, peeled, and homogenized using a food processor (Model MK-F300, Panasonic, Malaysia). The pumpkin puree was kept at 4±2°C before use.

2.3 Donut preparation

Rice donut was prepared according to the following recipe (% by total weight): 32.50% rice flour, 32.50% evaporated milk, 16.25% whole egg, 8.45% unsalted butter, 8.12% sugar, 1.95% leavening agent, and 0.23% salt. The dried ingredients were thoroughly mixed, including sifted rice flour, sugar, leavening agent, and salt. Melted butter, whole egg, and evaporated milk were hand-mixed and gradually added to the dry ingredients, and the batter was whipped for 3 mins until homogeneous. The batter (15 mL) was poured into a donut mold (5 cm diameter) and baked (800 Watt) for 2 mins using the doughnut maker (Homemate, Verasu Retail Co., Ltd., Thailand). The donut was kept in a polyethylene bag until analysis. In an experimental study, tested rice donuts were replaced for 0%, 10%, 20%, and 30% rice flour with coconut flour in all-butter against reduced-butter (butter/pumpkin puree = 75/25 w/w) conditions.

2.4 Physical analysis

Specific volume was determined by the rapeseed displacement method (AACC International, 2010) and reported as the volume-to-weight ratio. Samples were measured by the compression test using a texture analyzer (LRX Plus, Lloyd Instruments, Hampshire, UK). A cutting test cell was operated at a crosshead speed of 200 mm/min, and the hold peak (N) was reported as the firmness value. The muffin was cut horizontally with a knife and the crumb was measured for L^* (100 = white, 0 = black), a^* (+ = red, – = green) and b^* (+ = yellow, – = blue). A colorimeter (ColorFlex, Hunter Associates Laboratory, Reston, USA) was used.

2.5 Sensory evaluation

A total of sixty untrained panelists (age between 18–50 years) who regularly consume donuts were used to assess appearance, color, flavor, texture, and overall acceptability. Panelists were seated in individual booths, and rinsed the palate before testing by a 9–point hedonic scale (1 = extremely dislike, 9 = extremely like) (Lawless and Heymann, 1998). The quality index (QI) was calculated by the following equation (Fernandes and Salas-Mellado, 2017).

2.6 Statistical analysis

All experiments were carried out with three replicates. A two-way Analysis of Variance (ANOVA) with Duncan's test was performed at a 95% confidence level (Cochran and Cox, 1992). The SPSS software version 17.0 was used for data analysis and presented as mean ± standard deviation (SD). The perceptual mapping was analyzed by the principal component analysis (PCA) with the R-program (R Foundation for Statistical Computing, Vienna, Austria).

3. Results and discussion

3.1 Specific volume and firmness

Increasing the level of coconut flour replacement significantly decreased ($p<0.05$) rice donuts' specific volume but increased ($p<0.05$) firmness (Table 1). The control sample had the specific volume (1.84 mL/ g) and firmness (11.55 N) under all-butter as well as specific volume (1.80 mL/g) and firmness (12.35 N) at reduced-butter conditions. At 30% coconut flour replacement, the all-butter donut had the specific volume (1.47 mL/g) and firmness (16.18 N). In contrast, the reduced-butter donut showed the specific volume (1.49 mL/g) and firmness (17.71 N). Increasing the proportion of rice flour replaced with coconut flour (up to 30%) significantly lowered the specific volume and increased ($p<0.05$) the firmness of the rice donuts. It could be due to the influence of the difference in constituents between rice flour–11.9% moisture, 6.3% protein, 0.4% fat, 3.4%

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fiber, and 76.8% carbohydrate (Meherunnahar *et al*., 2018) and coconut flour – 3.7% moisture, 21.8% protein, 13.4% fat, 9.3% fiber, and 51.8% carbohydrate (Dat and Phuong, 2017). With a higher protein and fiber content, coconut flour absorbs water more rapidly than rice flour, providing a thickened batter. Still, lower total rice starch may affect the starch-forming network structure, starch retrogradation, and gas retention, resulting in a dense and harder texture, as explained by Jeong and Chung (2019).

In the 25% reduced-butter with pumpkin puree version, each formulation presented no difference in specific volume ($p>0.05$) but higher firmness ($p<0.05$) compared to the all-butter samples (Table 1). This was attributed to pectin in the pumpkin puree, which has a high water-binding capacity to maintain the gas cells and moisture. This results in an optimized batter consistency and a high-volume cake (Dadkhan *et al*., 2017). However, a firmer texture was found in each formulation with the reduced-butter condition against the all-butter condition. This was possibly due to the large increase in particle size in the rice flour (< 95 μm) blends by adding coconut flour (250–1,000 μm), reducing the firmness, as reported in the work of Kim and Shin (2014). Changing amylopectin transitions from an amorphous state to a crystalline one can increase the hardness of the products (Gomez and Colina, 2019). A supporting reason given by Singh *et al*. (2016) concerns gas cell destabilization, affecting the migration of free water and entrapment of air bubbles, allowing the evaporation of moisture before the baking time, resulting in a compact crumb.

The decreased fat in the reduced-butter condition lowered the amount of fat available to interrupt starch and protein interactions, leading to stiffening of the structure. This can accelerate moisture evaporation and concentrate the sugars and other ingredients in a recipe, causing irregularity of starch retrogradation and providing a more rigid texture (Bala *et al*., 2019). Hussien *et al*. (2016) agreed and explained that a reduced -butter cake containing squash and cantaloupe puree is harder due to having fewer air bubbles in the batter. A similar result was reported by Arifin *et al*. (2019), presenting a harder donut enriched with pumpkin puree. Having less fat lowers its emulsifying ability to coat and weaken the starch bonds, causing the continuity of starch and protein interactions within the structure, making the product more rigid. This observation is consistent with that of Croitoru *et al*. (2018), who observed reduced porosity in donuts made with black rice flour, relating to greater resistance during compression. The use of pumpkin puree (a moist fat replacer) might increase the water level in the formulation. This helps to solve the water imbalance, but only in the donut made with 10% coconut flour.

3.2 CIE color system

In the all-butter condition, the lowest values of lightness (L*), redness (a*), and yellowness (b*) were found in the rice donut with 0% coconut flour (control); the values increased when increasing the coconut flour level from 10% to 30% (Table 1), indicating a brighter, intensely red and yellow color. This may be due to an increase in the availability of amino groups with reducing sugars through the Maillard browning reaction, providing higher a* and b* (Bala *et al*., 2019).

Concerning reduced-fat rice donuts, L* and b* were increased with increasing coconut flour up to 30% coconut flour, while a* was decreased. Values of a* and b* were comparatively increased in reduced-fat donuts with added pumpkin puree against all-butter donuts. The finding was attributed to the pumpkin puree, which contains a bright orange-red pigment called β-carotene that provides a more red and yellow color than butter. It

Table 1. Physical properties of rice donuts incorporated with coconut flour in all- and reduced-butter conditions.

Parameter	Butter condition	Rice flour/coconut flour ratio (w/w)			
		100/0	90/10	80/20	70/30
Specific volume (mL/g)	All-butter	$1.84±0.18^{aA}$	$1.70±0.14^{bA}$	$1.57±0.12^{cA}$	$1.47±0.05^{cA}$
	Reduced-butter	$1.80±0.11^{aA}$	$1.75±0.12^{aA}$	$1.60±0.11^{bA}$	$1.49±0.08^{cA}$
Firmness (N)	All-butter	$11.55±0.08^{cB}$	$11.81±0.37^{cB}$	$14.10±1.48^{bB}$	$16.18±0.99^{aB}$
	Reduced-butter	$12.35±1.14^{cA}$	$13.83±1.29^{bcA}$	$14.81±0.81^{bA}$	$17.71±1.00^{aA}$
Lightness (L*)	All-butter	$68.08±1.71^{cA}$	$69.37±0.37^{bA}$	$71.38±0.73^{bA}$	$72.96±0.79^{aA}$
	Reduced-butter	$64.90±0.86^{cB}$	$68.76±0.54^{bB}$	$71.31±0.41^{aA}$	$71.60±0.37^{aB}$
Redness (a*)	All-butter	$0.77±0.08^{dB}$	$1.29±0.16^{cB}$	$1.43±0.07^{bB}$	$1.94±0.08^{aA}$
	Reduced-butter	$2.19±0.26^{aA}$	$2.20±0.23^{aA}$	$2.19±0.14^{aA}$	$1.99±0.10^{bA}$
Yellowness (b*)	All-butter	$18.71±0.14^{cB}$	$20.56±0.67^{bB}$	$21.11±0.57^{bB}$	$22.47±0.41^{aB}$
	Reduced-butter	$29.43±0.7^{bA}$	$28.55±0.38^{bA}$	$28.86±0.26^{bA}$	$31.89±0.66^{aA}$

Values are presented as mean±SD. Values with different lowercase superscripts within the same row (different butter conditions) are statistically significantly different ($p<0.05$). Values with different uppercase superscripts within the same column (different formulations) are statistically significantly different ($p<0.05$).

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is consistent with the work of Arifin *et al*. (2019), showing a more intensified redness and yellowness in cakes with pumpkin puree added.

3.3 Sensory analysis

The results of sensory evaluation are shown in Figure 1. Donuts containing 10% coconut flour received higher scores for all attributes compared to the control regardless of butter conditions. Furthermore, rice donuts with the reduced-butter condition had higher scores for color, flavor, texture, and overall acceptability, except for the appearance attribute than all-butter rice donuts. Increasing the proportion of coconut flour to 20% deteriorated consumers' preference for the donuts, reflected in lowered scores, and a further impact was observed at 30% coconut flour.

Regardless of butter conditions, incorporating 10% coconut flour made the rice donut more preferred, but from this level up to 30%, all sensorial attributes were scored lower (Figure 1). Most panelists liked the donut's texture, which was tender and softer than the control. It was possibly due to the coconut flour's high-water swelling, allowing the retention of gas bubbles for donut crumb expansion (Preichardt *et al*., 2011). This result is in line with the study of Kumar *et al*. (2018), which showed a reduction in the crumb hardness of gluten-free bread on highly water-binding seed powders from flax and acacia. At the same time, the 10% coconut flour donuts also received a high flavor score because of their high content of reducing sugars (glucose and galactose) (1.2–1.4%) and unique coconut flavor (Adeniran *et al*., 2019). Increasing both texture and flavor perception led to a rise in overall acceptability. Overall, the pumpkin puree seemed well-compatible and delectable with butter, promoting color, flavor, and texture attributes. The high oil-absorption capacity of coconut flour, essential for enhancing the mouthfeel and retaining flavor, is the main reason relative to developing the donut preference.

The sensory result was graph-presented to compare the perception of product attributes quickly. The graph has revealed the knowledge of all attributes based on the interdependency of coconut flour replacement and butter condition. It was somewhat clear to see the difference in samples, especially in color, flavor, and texture. The authors further calculated the concept's quality index (QI) based on the number of product attributes that determine their level of suitability and score liking. The index provides a framework for overall food evaluation showing a mean score by all attributes scores calculation. It is a vital measuring parameter to evaluate product acceptance. The scores for all attributes ranged between more than 5 (indifferent level) and less than 8 (like mostly). The average quality index or QI was different based on the formulations: for all-butter rice donuts with 0, 10%, 20%, and 30% coconut flour it was 70.5%, 81.6%, 65.6%, and 60.3%, respectively, and for reduced-butter donuts it was 71.7%, 82.5%, 66.2%, and 60.4%, respectively. A product with a minimum QI score of 70% is considered to have a good level of sensory acceptability (Fernandes and Salas-Mellado, 2017). Thus, the best-quality 10% coconut flour donut was prepared under the reduced-butter condition (QI = 82.5%), followed by the all-butter condition (QI = 81.6%).

3.4 Principal component analysis and perceptual

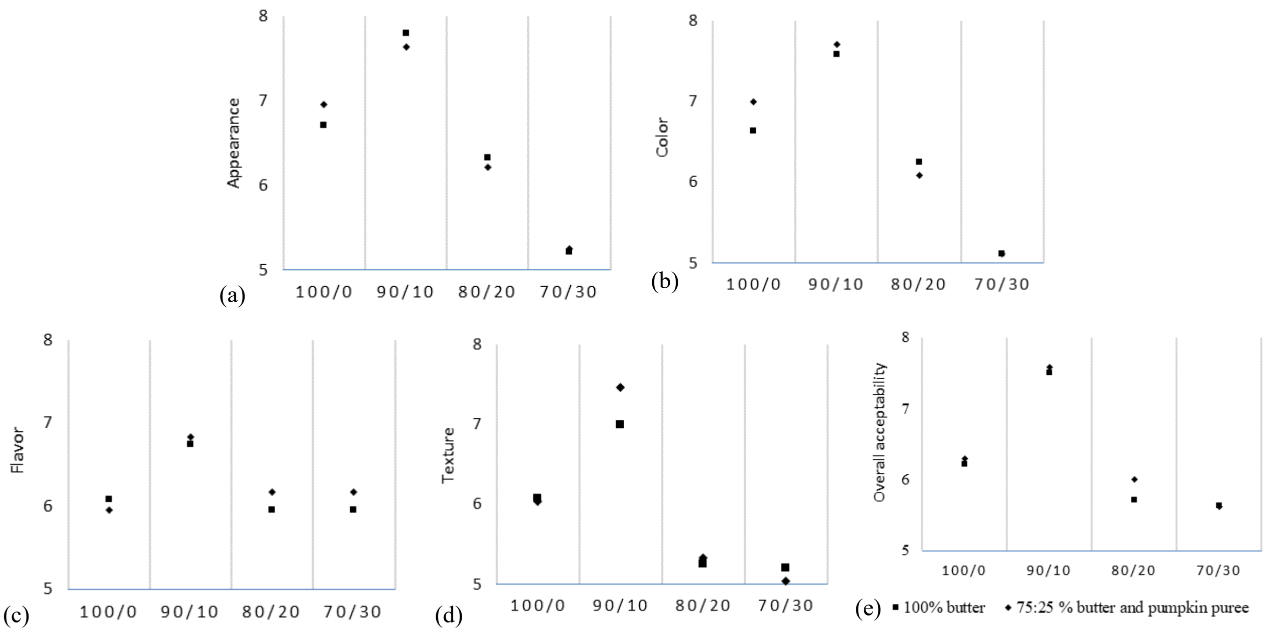

Figure 1. Sensory evaluation of rice donuts with coconut flour in all- and reduced-butter conditions: (a) appearance, (b) color, (c) flavor, (d) texture, and (e) overall acceptability.

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mapping

The PCA result in Figures 2a and 2b reveal the projection of variables and samples based on the relevance of physical and sensory properties. The biplot explains 78.37% of the total variability (Dim 1 – 55.95% and Dim 2 – 22.42% of the total variability), assuring that consumers can discriminate among the samples effectively. The result clearly distinguishes the three clusters (Figure 2). Cluster 1 is composed of samples with 10% coconut flour in all and reduced-butter conditions. Cluster 2 comprises samples with 0% and 20% coconut flour, followed by cluster 3 with 30% coconut flour samples in both butter conditions. In Figure 2a, Dim 1 is positively correlated with specific volume and all sensory attributes, including appearance, color, flavor, texture, and overall acceptability, but negatively correlated with firmness. In contrast, Dim 2 is positively correlated with L^*, a^*, and b^*. Rice donuts with 10% coconut flour (C10B and C10BP), which are positioned in the positive quadrant, are strongly differentiated by the highest specific volume, presenting a leavened crumb texture with preferable sensory attributes. On the contrary, the donuts with 30% coconut flour (C30B and C30BP) are positioned in the negative area, showing a harder crumb with unacceptable attributes.

Perceptual mapping differentiates samples from the most liked to the least. The 10% coconut flour, reduced-fat donut was positioned in the top upper quadrant, providing the most acceptable product with a higher flavor score. The result implies that the addition of 25% pumpkin puree could promote the flavor perception. However, the result indicates that the greater the coconut flour content, the lower the sensory acceptance.

4. Conclusion

A healthy gluten-free donut could be developed by replacing 10% of the rice flour with coconut flour and replacing 25% of the butter with pumpkin puree. Increasing the replacement level from 20% to 30% deteriorated physical properties, corresponding to lowered sensory perception of donuts. The use of pumpkin puree not only reduced the butter content but also promoted the donut quality, reflected in the higher texture and flavor scores.

Conflict of interest

The authors declare no conflict of interest.

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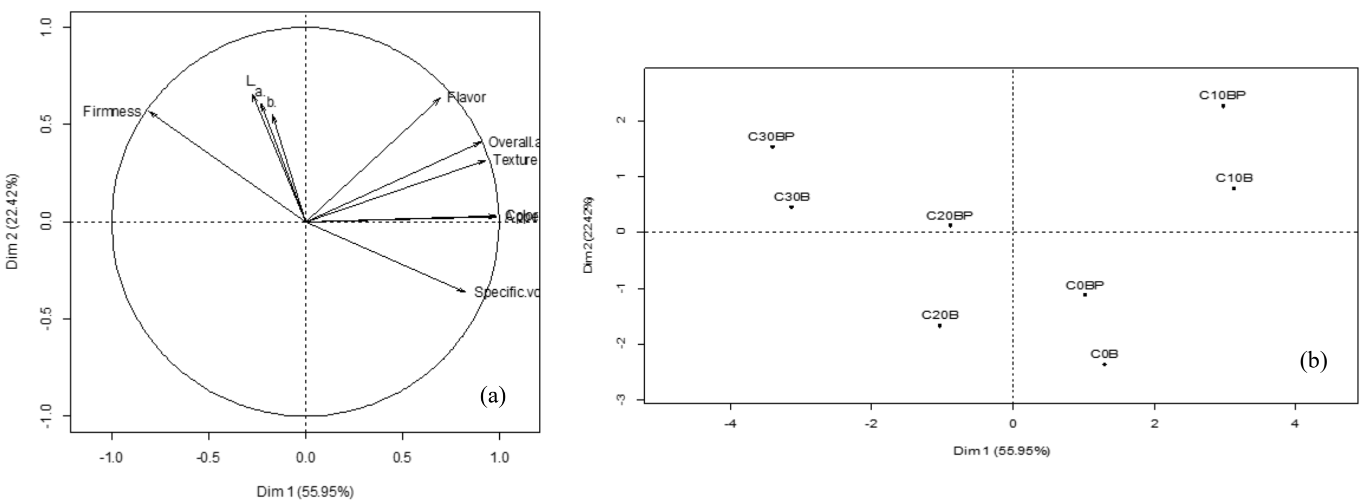

Figure 2. Perceptual mapping for rice donuts with coconut flour in all- and reduced-butter conditions: (a) projection of variables and (b) projection of samples. C0B, C10B, C20B, and C30B are rice donuts with 0, 10%, 20%, and 30% coconut flour, respectively, in all-butter conditions, and C0BP, C10BP, C20BP, and C30BP are rice donuts with 0, 10%, 20%, and 30% coconut flour, respectively, in reduced-butter condition.

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