INDONESIAN FOOD SCIENCE AND TECHNOLOGY JOURNAL (IFSTJ)

Journal homepage: online-journal.unja.ac.id/ifstj/issue/archive

QUALITY EVALUATION OF GLUTEN-FREE RICE DONUT INCORPORATED WITH EGGPLANT FLOUR AND XANTHAN GUM

Adisak Akesowan[#1], Apinya Chareonkul[1], Sirinard Tantakasem[1]

[#] *Department of Food Science and Technology, School of Science and Technology, University of the Thai Chamber of Commerce, 126/1 Vibhavadee-Rangsit Road., Dindaeng, Bangkok 10400, Thailand*

#Corresponding author *: E-mail: adisak_ake@utcc.ac.th*

***Abstract*— Incorporating functional ingredients for producing a healthy gluten-free product is necessary to assess the impact on product characteristics and acceptability. This study aimed to determine the effect of eggplant flour and xanthan gum on gluten-free rice donuts. Four donut formulations were prepared by replacing rice flour with 10% and 20% eggplant flour and adding 0.5% and 1% xanthan gum (flour weight basis). The rice donut was the control. Physical properties on specific volume, firmness, and color, as well as sensory evaluation on a 9-point hedonic scale, were investigated. When replacing rice flour with 10% eggplant flour, the donut with 1% xanthan gum showed better specific volume and firmness but was darker and received more acceptable than that with 0.5% xanthan gum. The 20% eggplant flour replacement deteriorated rice donuts' physical properties and sensory attributes. The preference mapping indicated that the rice donut with 10% eggplant flour and 1% xanthan was the best formulation.**

***Keywords*— Celiac disease, eggplant flour, food enhancement, gluten-free diet, xanthan gum**

Manuscript received 9 Aug. 2021; revised 27 Feb. 2022; accepted 20 Jun. 2022. Available online 31 July. 2022.

I. INTRODUCTION

Celiac disease, an autoimmune disease that damages the small intestine's villi when consuming gluten, often causes malnutrition, diarrhea, fatigue, weight loss, bloating, anemia, and osteoporosis [1]. The global incidence of this disease has increased by an average of 7.5% percent per year, fueling the food industry to develop gluten-free diets [2]. A gluten-free diet, which commonly means food without wheat, barley, and rye, is recommended as an existing treatment for celiac disease today. Rice flour has been widely used to replace wheat flour in several baked products, but rice-based products show different product characteristics and sensory attributes from wheat flour due to its bland and neutral taste. Rice flour has no gluten and does not absorb liquid and fat like wheat flour; thereby, it has a low baking quality [3]. Thus, gluten-free rice baked products are characterized by reduced textural and sensory properties against gluten-containing products. The development of a gluten-free diet that is palatable and healthy is of consumer's desire.

A gluten-free food with more nutrients, particularly dietary fiber, is beneficial for people with celiac disease. Eggplant flour, extracted from white eggplant fruit (*Solanum melongena*), is a nutraceutical ingredient with high total dietary fiber (42-45%), vitamins and minerals (vitamin C, B6, manganese, and magnesium), and antioxidants (polyphenols and anthocyanins) [4, 5]. It is reported that eggplant flour can reduce the risk of heart disease, diabetes, high blood pressure, cholesterol, obesity, tumors, memory loss, and cancer [6]. In agreement with the high quantity of fiber and antioxidants, eggplant flour is an excellent alternative to developing a high nutritional, gluten-free product.

The incorporation of hydrocolloids is extensively utilized and studied in gluten-free baked goods applications. With no gluten content, the rice batter had low consistency with less ability to retain air bubbles, allowing it to merge into a large size and finally evaporate before baking. It has caused a less specific volume and compact crumb in the final product. Hydrocolloids can thicken the gluten-free batter because they have a high affinity to bind water molecules. This retains the air bubbles dispersing in the batter and allows them to expand and give the product structure during baking [7]. Many studies have reported the relevance of increased batter viscosity and desirable crumb structure of final baked products, such as

Chinese steamed bread incorporated with sodium alginate and glucomannan [8] and gluten-free cake with xanthan gum [9]. Xanthan gum has unique physical and rheological properties, high water solubility, excellent heat resistance, and pH stability. This gum provides thickened and stabilized properties at low concentrations and has good compatibility with other gums and many starches [9].

Therefore, this study aimed to determine the effect of eggplant flour and xanthan gum on the quality of gluten-free rice donuts and assess the optimal formulation.

II. Material and Methods

A. Materials

All-purpose wheat flour (Kite®, UFM Food Centre Co., Ltd., Bangkok, Thailand), tapioca starch (Five Stars Fish brand®, ETC International Tradings Co., Ltd., Nonthaburi, Thailand), and other ingredients included unsalted butter, low-fat milk, whole egg, leavening agent, salt, and sugar were purchased from a supermarket. Xanthan gum (Keltrol®, CP Kelco, San Diego, CA, USA) was used.

B. Methods

Preparation of eggplant flour

Eggplant fruits (*Solanum melongena*) were washed, peeled, transversely cut (1 cm thickness), and blanched in boiling water for 1 min. Drying in a tray dryer at 55 ± 2 °C for 8 h, ground by a Waring® blender (Model 7011S, Waring Commercial, CT, USA), and sieved through a 50-mesh Restch test sieve (Verder Scientific Inc., PA, USA). The flour was kept in a refrigerator (10 ± 2 °C) before use.

Preparation of rice donut

The regular rice donut recipe (% flour weight basis (fwb)) included 100% rice flour, 74% milk, 37% whole egg, 26% unsalted butter, 15% sugar, 6% leavening agent, and 0.7% salt. Initially, whipped whole egg and sugar for 2 min using a food processor with a high speed. Add rice flour, leavening agent, and salt, and hand-mixed thoroughly. Milk and melted butter were added and then mixed for 3 min until homogeneous. The batter (15 ml) was poured into a donut mold (5 cm diameter) of the doughnut maker (Homemate, Verasu Retail Co., Ltd., Bangkok, Thailand) and baked (800 Watt) for 2 min. The donut was kept in a polyethylene bag until analysis. For the experimental study, rice donuts were formulated with eggplant flour replacement at 10% and 20% (w/w) and xanthan gum addition at 0.5% and 1% (fwb) as an additional ingredient.

Physical analysis

Specific volume was determined according to the rapeseed displacement method [10]. A sample was initially weighed, then determined the volume by a cylinder. The specific volume was calculated as the volume-to-weight ratio.

Firmness was measured using a texture analyzer (LRX Plus, Lloyd Instruments, Hampshire, UK) equipped with a cylinder probe (35 mm diameter), operating at a 200 mm/min crosshead speed. The compression was 50% of the sample height, and the peak force (N) was recorded.

The sample was cut vertically with a knife, and the crumb was measured using a HunterLab digital colorimeter (MiniScan EZ, Hunter Associates Laboratory, Reston, VA). L^*(lightness) (100 = white, 0 = black), a^*(+ = red, - = green) and b^*(+ = yellow, - = blue) were recorded. Hue angle ($h°$) was calculated as follows: Hue = arctan b^*/a^*.

Sensory evaluation

Sixty untrained panelists (18–50 years), who regularly consume donuts, were chosen from the students and staff in the Department of Food Science and Technology at the University of the Thai Chamber of Commerce in Thailand. They assessed the samples' color, taste, texture and overall acceptability using a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like). The test was performed in individual booths with three-digit numbers coded samples. Panelists were instructed to rinse their palates before testing each sample.

Statistical analysis

All analyses were carried out in triplicate. Data were analyzed by the analysis of variance (ANOVA) at the 95% confidence level using the SPSS software version 17.0. Means with a significant difference ($p<0.05$) were compared using Duncan's new multiple range test [11]. The preference mapping was analyzed by the principal component analysis (PCA) using the program R (R Foundation for Statistical Computing, Vienna, Austria).

III. Result and Discussion

Physical properties

Results in Table 1 reveal that the change in specific volume depended on the levels of eggplant flour replacement in rice donuts. With 10% eggplant flour replacement it caused a reduced amount of total rice flour. A less leached amylose caused a lower starch gelatinization, resulting in a thin batter. The chemical composition of eggplant flour includes 5.3% moisture, 12.6% protein, 1.8% fat, 12.7% fiber, 61.2% carbohydrate [12], while rice flour contains 11.9% moisture, 6.3% protein, 0.4% fat, 3.4% fiber, 76.8% carbohydrate [13]. Thus, the addition of eggplant flour increased the amounts of protein and fiber in the composite flour, relating to the higher water-binding capacity of the batter. The thickened batter is essential for the air bubbles and moisture retention, and structure of starch polymers. At the same time, the addition of xanthan gum, a high water-absorbing hydrocolloid, helps increase the batter consistency. Although incorporating 0.5% xanthan gum increased the batter consistency, the donut still presented a lower specific volume ($p<0.05$). It noted that 1% xanthan inclusion was a better amount because it raised the specific volume similar to the control. It might be due to a higher water-holding capacity that allows starch molecules to solubilize in the supernatant completely. This increases the number of soluble starch granules for water molecules interactions, resulting in a good dough structure [8]. A similar result was reported by Sciarini et al. [14], showing the increased bread batter consistency with xanthan and carboxymethylcellulose, producing a high bread-specific volume. On the contrary, a batter was too viscous with 20% eggplant flour and either 0.5% or 1% xanthan gum. It causes a reduction in air bubbles formation and retention, creating a dense texture and low specific volume.

The batter viscosity plays a crucial role in maintain the phase separation and ensuring it to happen at the appropriate time during the baking process. The much more flours with 20% eggplant flour replacement caused the highest donut firmness. The high dense batter reduced the air bubble entrapment and free water migration, affecting the structure expansion [7]. The donut with 10% eggplant flour and 1% xanthan showed a firmness similar to the control. It is because xanthan gum provides thickening and stabilizing effects on emulsions and suspensions. This stabilized total starch's viscosity, leading to inhibition of starch granule association and retrogradation, which facilitates the gas expansion and retention, and finally increases the muffin volume [15]. A similar result by Eduardo et al. [16] showed the impact of the water-binding capacity of carboxymethylcellulose and high-methoxyl pectin. They could decrease starch swelling and amylose leaching, reducing the firmness of composite cassava–maize–wheat bread.

TABLE I
PHYSICAL PROPERTIES OF RICE DONUTS WITH EGGPLANT FLOUR AND XANTHAN GUM

Para-meters	**Control**	**10% eggplant flour**		**20% eggplant flour**	
		0.5% xanthan	**1% xanthan**	**0.5% xanthan**	**1% xanthan**
Specific volume (cm^3/g)	2.25±0.24^a	1.88±0.16^b	2.41±0.40^a	1.44±0.30^c	1.59±0.25^c
Firm-ness (N)	9.85±0.44^c	11.16±0.23^b	9.19±0.30^d	12.65±0.29^a	12.89±0.51^a
L^*	65.24±1.10^a	55.55±0.15^b	54.00±0.77^b	50.83±1.10^c	49.14±0.82^d
a^*	4.88±0.21^a	3.17±0.07^b	4.57±0.74^a	3.15±0.25^b	2.90±0.49^b
b^*	24.87±0.22^c	24.34±0.13^c	26.23±0.70^a	25.35±0.69^b	25.70±0.22^b
$h°$	78.88±0.26^b	82.56±0.13^a	80.13±0.74^a	82.91±0.41^a	83.57±1.03^a

Means in the same row with different superscripts are different ($p<0.05$).

The linear regression model of the donut given in Figure 1 is $y = -3.1905x + 17.446$ ($R^2 = 0.9072$, $r = -0.95$), defining a high negative correlation between firmness and specific volume. The high coefficients of determination (R^2) values indicate the reliability of the equations for changes of responses. Thus, the models correlate well with the experimental values and denote that a specific volume's lower value leads to a harder donut crumb.

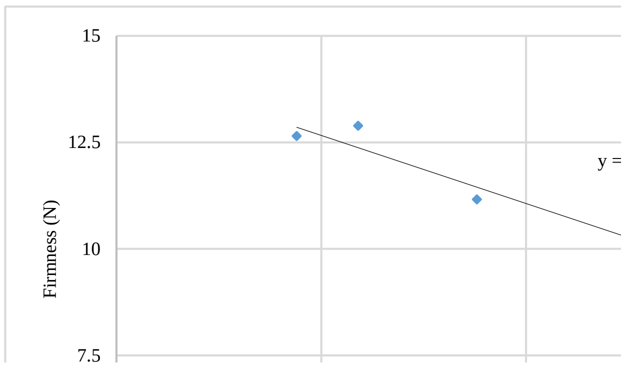

FIGURE 1
CORRELATION OF FIRMNESS AND SPECIFIC VOLUME OF RICE DONUTS WITH EGGPLANT FLOUR AND XANTHAN GUM

Color scales L^*, a^*, and b^* values significantly differed between the control and donuts with eggplant flour and xanthan. It was attributed to the eggplant flour's brown color, which lowered L^* values when increasing from 10% to 20% replacement. The changes in a^* and b^* values fluctuated; thus, the calculated $h°$ was used to explain the color shade. The donut with 20% eggplant flour and 1% xanthan had the highest $h°$ (83.57), indicating that it became more intensively green than the control ($h°$ = 78.88).

Sensory evaluation

Results of the hedonic scale of donuts with eggplant flour and xanthan gum are presented in Figure 2. Incorporating eggplant flour and xanthan gum lowered all attributes scores, particularly at 20% eggplant flour inclusion. Most panelists did not prefer the donuts with 20% eggplant flour, as they felt them look darker, compact, and harder, as well as had detected an unwanted taste and flavor from eggplant flour itself. Among all attributes, taste and flavor scores were remarkably dropped from the control, possibly due to the xanthan gum's flavor that masked the original donut aroma, as reported in the study of Chochkov et al. [17]. The decrease in sensory attributes like appearance, color, taste, flavor, and texture lowered overall acceptability.

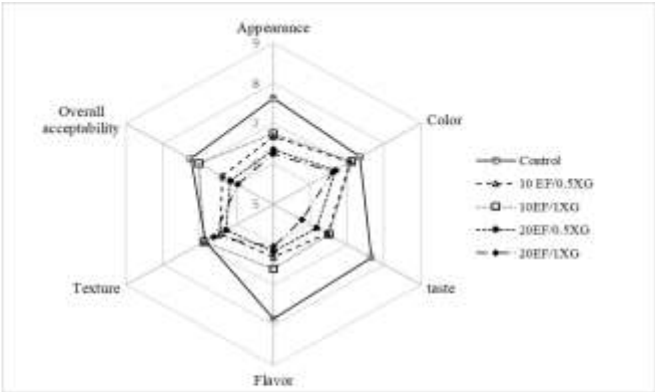

FIGURE 2
SENSORY EVALUATION OF RICE DONUTS WITH EGGPLANT FLOUR AND XANTHAN GUM

Among all formulations, the 10% eggplant flour replacement and 1% xanthan addition produced a donut with a desirable texture similar to the control, consequently influencing the higher overall acceptability score. The sample was the most acceptable with a "like moderately" response. The high fiber content of eggplant flour and high xanthan's water affinity leads to entrapping moisture and air cells within the starch-protein structure. The suitable batter viscosity could retain the tiny air bubbles, reduce their coalescence, and release gases in the baking time, resulting in a desirable crumb texture [18].

ANOVA revealed the mean values of attributes with significant differences but no trend of a preferred sample. Principal component analysis or PCA was suggested to construct the preference mapping, a tool for describing the relevance of physical and sensory attributes and identifying the best sample formulation.

Preference mapping

The PCA result in Figure 3a shows that Dim 1 and Dim 2 explained 80.6% and 14.97% of the total variability. The high cumulative value (95.57%) implies that the consumers can effectively discriminate the samples. The Dim 1 axis revealed a positive correlation with specific volume and all sensory attributes, including appearance, color, flavor, texture, and overall acceptability. At the same time, the firmness presented a negative correlation. Dim 2 was positively correlated with *b**. The result indicates a significant distribution of the prominent discrimination subjecting to the eggplant flour replacement. The control, positioned in the positive quadrant, was characterized by the highest specific volume, presenting a leavened crumb texture with preferable sensory attributes (Figure 3b). Contrary to the donuts with 20% eggplant flour and 0.5% or 1% xanthan, positioned far from the control. They showed a harder crumb with lower specific volume, suggesting the greater the eggplant flour, the lower the sensory acceptance, reducing the consumer preference.

According to Figure 3b, the donut with 10% eggplant flour with 1% xanthan was closer to the control than that with 0.5% xanthan. This indicated that the donut with 10% eggplant flour and 1% xanthan was more acceptable, which might be due to its tender texture influencing by xanthan's high water retention effect.

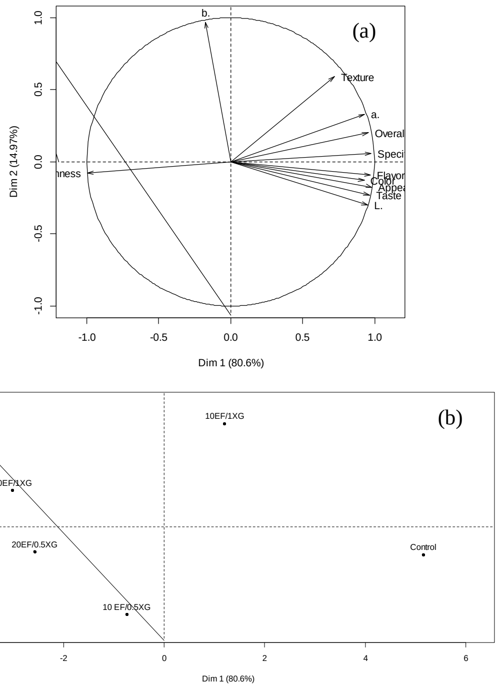

FIGURE 3
PREFERENCE MAPPING OF RICE DONUTS WITH EGGPLANT FLOUR AND XANTHAN UM: (A) PROJECTION OF VARIABLES AND (B) PROJECTION OF SAMPLES

IV. CONCLUSION

Eggplant flour and xanthan gum showed the potential to develop the quality characteristics of rice donuts. The 20% rice flour replacement with eggplant flour reduced specific volume and increased firmness, deteriorating donut sensory characteristics. The rice donut replaced with 10% eggplant flour and 1% xanthan gum had better specific volume and firmness, leading to a high texture and overall acceptability. The result suggests basic information on eggplant flour and xanthan gum usage for quality improvement and nutritional fortification of rice donuts. The adjustment of the donut recipe, such as a balance of flour and liquid portion, is needed for further study.

REFERENCES

[1] I, Demirkesen, G, Sumnu, S, Sahin. Quality of gluten-free bread formulations baked in different ovens. Food and Bioprocess Technology 2013, 6: 746-753.

[2] JA, King, J, Jeong, FE, Underwood, et al. Incidence of celiac disease is increasing over time: a systematic review and meta-analysis. American Journal of Gastroenterology 2020, 115: 507–525. Doi:10.14309/ajg.0000000000000523

[3] RM, Guimarães, TC, Pimentel, TAM, de Rezende, J, de Santana-Silva, HG, Falcão, EI, Ida, MB, Egea. Gluten-free bread: Effect of soy and corn co-product on the quality parameters. European Food Research and Technology 2019, 245: 1365-1376.

[4] U, Uthumporn, A, Fazilah, AY, Tajul, M, Maizura, AS, Ruri. Physico-chemical and antioxidant properties of eggplant flour as a functional ingredient. Advance Journal of Food Science and Technology 2016, 12: 235-243.

[5] JS, Dias. Nutritional quality and health benefits of vegetables: A review. Food Nutrition and Science 2012, 3: 1354-1374.

[6] P, Nandi. Accessed 12 March 2019. The amazing benefits of eggplants. https://askdrnandi.com/health-benefits-eggplant/

[7] EP, Lopéz, PL, Jimémez. Effect of different proportions of brea gum in the functional characteristics of wheat flour starch: Impact on the physical quality of bread. Food science and Technology (Campinas) 2016, 36. Doi:10.1590/1678-457X.0030

[8] SY, Sim, AA, Aziah, LH, Cheng. Characteristics of wheat dough and Chinese steamed bread added with sodium alginate and konjac glucomannan. Food Hydrocolloids 2011, 25: 951-957.

[9] LD, Preichardt, CT, Vendruscolo, MA, Gularte, AS, Moreira. The role of xanthan gum in the quality of gluten free cakes: Improved bakery products for celiac patients. International Journal of Food Science and Technology 2011, 46: 2591-2597.

[10] AACC International, “Approved Methods of Analysis”, 11th ed. AACC International, St. Paul, MN, 2010

[11] WG, Cochran, GM, Cox, “Experimental Designs”, 2nd ed. John Wiley and Sons, New York, 1992

[12] LQ, Dat, VTH, Phuong. Functional properties and influences of coconut flour on texture of dough and cookies. Veitnam Journal of Science and Technology 2017, 55: 100-107.

[13] M, Meherunnahar, RS, Chowdhury, MM, Hoque, MA, Satter, MF, Islam. Comparison of nutritional and functional properties of BK2 foxtail millet with rice, wheat and maize flour. Progressive Agriculture 2018, 29: 186-194.

[14] LS, Sciarini, PO, Ribotta, AE, León, GT Pérez. Effect of hydrocolloids on gluten-free batter properties and bread quality. International Journal of Food Science and Technology 2010, 45: 2306-2312.

[15] JP, Singh, A, Kaur, N, Singh. Development of eggless gluten free rice muffins utilizing black carrot dietary fibre concentrate and xanthan gum. Journal of Food Science and Technology 2016, 53: 1269-1278.

[16] M, Eduardo, U, Svanberg, L, Ahrné. Effect of hydrocolloids and emulsifiers on baking quality of composite cassava-maize-wheat breads. International Journal of Food Science 2014. Doi:10.1155/2014/479630

[17] R, Chochkov, D, Zlateva, M, Dushcova, S, Topleva. Effect of hydrocolloids on properties of dough and quality of gluten-free bread enriched with whey protein concentrate. Ukrainian Food Journal 2019, 8: 533-543.

[18] S, Martinez-Cervera, T, Sanz, A, Salvador, SM Fiszman. Rheological, textural and sensorial properties of low-sucrose muffins reformulated with sucralose/ polydextrose. LWT-Food Science and Technology 2012, 45: 213-220.