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Research article

Gluten-free pancakes and waffles prepared from Riceberry flour instant mix with xanthan gum addition: physical, sensory and chemical properties

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Abstract

Importance of the work: Pancakes and waffles are popular breakfast and dessert items commonly made from wheat flour containing gluten. Riceberry flour has the potential to be used to create gluten-free baked products. However, the lack of the gluten structure influences the quality of waffles and pancakes.

Objectives: To investigate the effect of xanthan gum on the quality of gluten-free waffles and pancakes made from Riceberry flour.

Materials & Methods: Physical quality measurements were made of the pancake spread ratio, the percentage weight loss during cooking and the color. Sample texture was measured using a CT-3 Brookfield texture analyzer. The sensory acceptability was conducted using a 9-point hedonic scale. The moisture content and water activity of all samples were measured.

Results: Xanthan gum addition resulted in decreases in the percentage weight loss during cooking and in the spread ratio of the pancakes. The pancake shear force decreased with xanthan gum addition (0.25–1%). Furthermore, this addition decreased the hardness, chewiness and gumminess of the waffles, while increasing their springiness. Waffles and pancakes with 0.5% added xanthan gum received the highest acceptable scores that were significantly higher than the control samples.

Main finding: The optimum amount of xanthan gum addition to improve the quality of gluten-free waffles and pancakes made from Riceberry flour was 0.5%. This addition retained more moisture in the products than the control and provided a viscoelastic network that mimicked gluten in the final products.

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Introduction

Riceberry (*Oryza sativa L.*) is a dark-purple pigmented rice variety that was created by combining two rice varieties—a purple rice variety (Jao Hom nin) and Thai Hom mali rice (Khoa Dawk Mali 105) (Riceberry, n.d.; Leardkamolkarn et al., 2011). Riceberry is abundant in fiber and antioxidants, such as anthocyanins, beta-carotene, gamma-oryzanol, vitamin E, tannins, zinc and folate (Settapramote et al., 2021). Hence, Riceberry is a healthy stable food and suitable for people of all ages as it can be ingested to preserve health and used in place of white or brown rice (Riceberry, n.d.). Nutrients found in Riceberry may reduce the risk of chronic diseases, such as cancer, type 2 diabetes, hypertension, cardiovascular disease and dementia (Leardkamolkarn et al., 2011; Thiranusornkij et al., 2019; Settapramote et al., 2021). Furthermore, Riceberry does not contain gluten which is a protein structure found in wheat flour (Leardkamolkarn et al., 2011; Rai et al., 2018). Hence, Riceberry flour can be an alternative flour for making gluten-free products. Celiac disease, one of the most common hereditary illnesses, is triggered by gluten ingestion that impacts approximately 1% of the population (Fasano et al., 2003; Tjon et al., 2010; Cash et al., 2011; Ronie et al., 2021). When gluten-containing foods is consumed, the immune system attacks the gastrointestinal system tissues, resulting in a variety of symptoms, such as diarrhea, abdominal pain and bloating, with the only cure being to avoid gluten in the diet (Rai et al., 2018; Rakkhumkaew et al., 2019).

Several studies have developed gluten-free bakery products from Riceberry flour, such as brownies, cookies and bread (Sirichokworrakit et al., 2015; Rakkhumkaew et al., 2019; Thiranusornkij et al., 2019; Chusak et al., 2020). A gluten-free mix from Riceberry flour was developed to produce waffles that was used to study the effect on postprandial glycemic response in humans (Tongkaew et al., 2021). However, the quality of pancakes and waffles made from Riceberry flour in terms of physical, sensory and chemical properties has not been investigated. The current study aimed to fill this information gap.

Waffles and pancakes are popular western-style breakfast and dessert items offered in Thai cafes, often using the same flour base was in the waffle and pancake preparation that is mainly made with wheat flour containing gluten (Huber and Schoenlechner, 2017; Pholfoodmafia, 2017). As a result, celiac disease sufferers are unable to consume these products. Studies have utilized a mixture of gluten-free flour, such as rice flour, glutinous rice flour and tapioca flour to substitute wheat flour in bakery items (Julianti et al., 2017; Rakkhumkaew et al., 2019). However, the texture quality of these baked goods may differ from those created using wheat flour due to a lack of gluten structure. Therefore, several hydrocolloids, such as guar gum and xanthan gum, may be added to the flour mix to improve the textural features of gluten-free products. Xanthan gum is another prominent hydrocolloid utilized in gluten-free products because of its stability at high temperatures and acidic conditions (Sciarini et al., 2010; Culetu et al., 2021). Xanthan gum can bind water and form a viscoelastic network that serves as the framework of gluten-free items, particularly bakery products, such as bread, cake and cookies (Rathnayake et al., 2018; Culetu et al., 2021).

Therefore, the goal of this study was to examine how adding xanthan gum to the instant mix from Riceberry flour affected the physical, textural and sensory qualities of waffles and pancakes. This research also investigated improvement to the quality of gluten-free waffles and pancakes made from Riceberry flour to have acceptable properties. These Riceberry waffles and pancakes could be alternatives for consumers who need to avoid wheat flour products, and so may attract more customers, expanding Riceberry consumption and expanding consumer groups in both domestic and international markets.

Materials and Methods

Waffle and pancake preparation

Riceberry grain, glutinous rice flour, tapioca flour, corn flour, sugar and salt were purchased from Supercheap Co. Ltd, (local supermarket in Phuket, Thailand). Baking powder and xanthan gum were purchased from Gerbera house shop (Phuket, Thailand). Riceberry flour was obtained by grinding Riceberry grain in a blender (HR2115; Phillips; Thailand) for 5 min at setting number 5 and sifting through a 60-mesh sieve. The formulation of rice flour mixture of Riceberry flour, tapioca flour, corn flour and glutinous flour was modified from a preliminary study (Phongnarisorn et al., 2018). The xanthan gum addition was varied to five levels of 0% (control), 0.25%, 0.5%, 1% and 2%, as shown in Table 1. After weighing all the dry ingredients, the rice flour mixture, baking powder, milk powder and xanthan gum were mixed in the blender for 3 min.

Table 1 Formulations for gluten-free waffles and pancakes

Ingredient (g)	Level of xanthan gum addition (% weight per weight of dry ingredient)				
	0% (control)	0.25%	0.5%	1%	2%
Riceberry flour	30	30	30	30	30
Tapioca flour	15	15	15	15	15
Corn flour	10	10	10	10	10
Glutinous rice flour	15	15	15	15	15
Baking powder	3	3	3	3	3
Salt	1.5	1.5	1.5	1.5	1.5
Sugar	22	22	22	22	22
Milk powder	15	15	15	15	15
Oil	10	10	10	10	10
Water	60	60	60	60	60
Egg	50	50	50	50	50
Xanthan gum	0	0.28	0.57	1.14	2.28

Then, the mixed dry ingredients of each formulation were mixed with the liquid ingredients consisting of 60 g of water, 50 g of egg and 10 g of vegetable oil, to make the batter. For the waffles, a tablespoon of batter (15 mL) was added to each waffle pan in a waffle maker (HOM-WS06; Homemate; USA) and cooked for 3 min at 180–190 °C. For the pancakes, a tablespoon of the batter (15 mL) was cooked in a pan that was heated to 180–190 °C for 2 min before the pancake was flipped and cooked for another 1 min.

Evaluation methods for physical properties

Flow rate or consistency of batter and weight loss of pancake during cooking

The flow rate of the batter was measured using a standard 24 cm Bostwick consistometer (CSC Scientific Co. Inc.; USA). The batter was filled into the compartment and the top was leveled off using a spatula. The trigger was pressed down to open the gate. The distance of batter that flowed in the trough of the Bostwick consistometer after 1 min was measured and the maximum reading at the center of the trough was recorded. The flow rate was calculated by dividing the distance by the time. Three measurements were performed and averaged. The batter of the pancake was weighed before cooking and after cooking and cooling for 1 h. The weight loss was calculated using Equation 1 which was adapted from Matos et al. (2014):

$$\% \text{ Weight loss} = [(W_0 - W_1) / W_0] \times 100 \quad (1)$$

where W_0 is the weight of batter and W_1 is the weight of the pancake after cooking and cooling for 1 h. Each formula was analyzed for nine replications.

Width and thickness of Riceberry pancakes

The width of the pancake of each formulation was measured using a metric ruler by placing six pieces of pancake next to each other without overlapping. The total width was measured and the width of each formulation was calculated by dividing by 6. The thickness was measured by placing six pieces of pancake on top of each other and measuring the total height. The thickness of each formulation was calculated. The measurement of each formulation was conducted in five replications. The spread ratio of a pancake was calculated by dividing the width of the pancake by the thickness of the pancake, according to American Association of Cereal Chemists International (2010) and Bettge (2014).

Color measurements

The color measurements were determined at room temperature (25–30 °C). The color of the waffles and pancakes was measured using the CIE color system HunterLab colorimeter (MiniScan® XE Plus; USA). The color values were expressed as L* for brightness and darkness, a* for redness and greenness and b* for yellowness and blueness.

Texture analysis of waffles and pancakes

Texture analysis of the Riceberry flour waffles was measured using a CT-3 texture analyzer meter (Brookfield Amtek; USA) using a cylindrical probe (TA-AACC36) at a speed of 1 mm/s at a distance of 25% of the deformation height of the sample (2 cm × 2 cm × 1 cm). Then, the probe moved back at a speed of 5 mm/s. After that, the probe pressed the sample again at the same speed for the texture profile analysis (TPA). Four texture attributes were defined as part of the texture profile of the waffle samples: hardness, springiness, chewiness and gumminess. Then, the cylindrical probe was changed to a cutting probe (TA-SBA-WB-1) that cut the sample in the middle at a speed of 2 mm/s with a cutting force of 500 g at a distance of 10 mm to measure the cutting shear force based on the compression method (Beitane et al., 2014; Shih et al., 2006). For the pancakes texture analysis, only the shear force was measured using the same methods as for the cutting probe because the thickness of the pancakes varied in the range 0.3−1.2 cm, which was not suitable for measurements using the TPA method.

Sensory evaluation methods

Acceptability of the Riceberry waffle and pancake was evaluated using 9-point hedonic scales where 1 point represented dislike extremely and 9 points represented like extremely. The evaluated attributes were appearance, color, texture, aroma, taste and overall acceptability. Both male and female participants were recruited from the Phuket Rajabhat University staff and undergraduate students. According to Świąder and Marczewska (2021), 50 untrained participants were adequate for sensory evaluation and were recruited to evaluate the waffles and pancakes separately. Each formulation of waffle and pancake was assigned a three-digit code and samples (approximately 5 g of each formulation) were randomly distributed to the participants who evaluated each sample by observing and tasting the samples. Participants were given separate cups of water to rinse their mouths and wash away any residual taste between samples (Gacula and Rutenbeck, 2006).

Chemical composition analysis

The moisture contents of the Riceberry flour waffle and pancake samples were measured using standard methods (Association of Official Analytical Chemists, 2005). Water activity was measured using a water activity meter (Aqualab; series 4TEV; USA). The Riceberry flour waffle formulation with a control and selected products from the sensory evaluation were chosen for proximate composition analysis (moisture, ash, protein, fiber and fat) using standard methods (Association of Official Analytical Chemists, 2005). The carbohydrate content was calculated by subtracting 100 from the sum of proximate composition percentages in the sample (moisture, ash, protein, fiber and fat). The total energy measure in kilocalories per 100 g of each product was determined using Equation 2 (Mullan, 2008):

$$\text{Energy} = (\%\text{Protein} \times 4) + (\%\text{Fat} \times 9) + (\%\text{Carbohydrate} \times 4) \quad (2)$$

Statistical analysis

All data were statistically analyzed using the SPSS program (version 18; SPSS Inc.; USA). The results were presented as mean ± SD. Analysis of variance was used to determine the differences based on Duncan's multiple-range test at the 95% confidence interval. A randomized complete block design was used for sensory evaluation. A completely randomized design was used for the physical properties, texture profile and chemical analysis, and for the moisture content and water activity. Differences in the proximate composition between the control and 0.5% added xanthan gum to the instant mixes for waffles and pancakes were analyzed based on a two-sample t test.

Results and Discussion

Flow rate of batters using Bostwick consistometer and physical properties of pancakes

The flow rate of the batter decreased due to the addition of more xanthan gum, as shown in Table 2. The flow rate on a Bostwick consistometer indicates the viscosity of batter as a more viscous mixture flows more slowly than a mixture with a lower viscosity. This result showed that xanthan addition increased the viscosity of the mixture while slowing the flow rate of the batter. The spread ratio of the pancake samples was lower because the thicker batter spread less, resulting in thicker pancakes with a smaller diameter. For all samples, a scoop (1 tablespoon/15 mL) of batter was fried on the pan; however, the weight differed significantly as the addition of xanthan increased. The weights of a scoop of batter differed due to the higher water-binding ability with increased xanthan gum addition. As a result, the weight of the pancake increased as the amount of xanthan gum addition increased due to its capacity to bind water. Furthermore, as the xanthan gum addition increased, the weight loss of pancakes during cooking reduced (Table 2) because during cooking of pancakes, the fluid evaporated, resulting in weight loss. This finding showed that a higher xanthan gum addition greatly increased moisture retention in the pancakes, as shown in Table 4. This finding was consistent with the results of Itthivadhanapong et al. (2016) who reported that gluten-free, steamed rice cakes with 1% xanthan gum addition had a slightly higher moisture content and with the results of Preichardt et al. (2011), who showed that 0.2–0.4% xanthan gum

Table 2 Results of flow rate (consistency) of batters using a Bostwick consistometer (n = 3) and physical properties of pancakes (n = 5)

	Level of xanthan gum addition (% weight per weight of dry ingredient)				
Measurement	0% (control)	0.25%	0.5%	1%	2%
Flow rate of batter (cm/s)	6.20±0.45^{a}	0.61±0.05^{b}	0.15±0.01^{c}	0.06±0.00^{d}	0.01±0.00^{e}
Weight (g) per piece of pancake	10.87±1.09^{d}	12.24±0.98^{cd}	14.07±1.06^{c}	16.44±1.66^{b}	18.88±3.37^{a}
%Weight loss during cooking	33.86±3.13^{a}	20.16±2.35^{b}	16.59±2.21^{c}	7.14±2.37^{d}	4.87±1.68^{e}
Diameter/Width (cm)	6.93±0.06^{a}	6.25±0.05^{b}	5.68±0.24^{c}	4.56±0.11^{d}	3.61±0.05^{e}
Thickness (cm)	0.32±0.01^{e}	0.38±0.01^{d}	0.61±0.01^{c}	0.96±0.03^{b}	1.25±0.01^{a}
Spread ratio	21.52±0.55^{a}	16.46±0.59^{b}	9.30±0.48^{c}	4.74±0.18^{d}	2.89±0.03^{e}

Mean ± SD in same row superscripted with different lowercase letters are significantly (p < 0.05) different.

addition increased the moisture content of gluten-free cupcakes. In addition, Noorlaila et al. (2020) discovered that the addition of 1% xanthan gum increased the volume of the cake when compared with the control because the batter viscosity was related to the density and specific gravity of the sponge cake. Rakkhumkaew (2017) discovered that 1% xanthan gum improved the specific volume of Riceberry flour bread by improving dough development and gas retention due to increasing dough viscosity. However, adding 2% xanthan gum resulted in a drop in the loaf-specific volume, particularly in the bread which had the lowest loaf-specific volume of all gluten-free bread samples (Rakkhumkaew, 2017).

Furthermore, the control batter (0% xanthan gum) was thin and runny, therefore the round-shape molds were placed in a pan to shape the batter. Because the pancake batter was cooked in a pan the batter was permitted to spread according to its flow rate after being poured into the pan. As a result of its higher flow rate (6.20 cm/s), the control samples had the highest spread ratio. The batter of samples containing 2% xanthan gum held their shape and stayed stable when cooked in the pan due to their high viscosity, with a flow rate of 0.01 cm/s as it flowed very slowly on a Bostwick Consistometer. It produced the thickest, heaviest pancakes with the smallest diameter. This result revealed that a 2% xanthan gum addition may not be appropriate for pancakes because it produced a dense crumb and an unappealingly thick batter for pancakes. The spread ratio findings coincided with Renzetti and Arendt (2009), who hypothesized that a lower batter consistency promotes batter expansion. Furthermore, Sciarini et al. (2010) demonstrated that xanthan gum inclusion in batter and bread resulted in the highest batter consistency and specific volume compared to other hydrocolloids (carrageenan, alginate, carboxymethylcellulose and gelatin).

The addition of xanthan gum to the mixture influenced the color of the waffles, as indicated in Table 3. The L* values in the control and other samples were significantly different. Xanthan gum tended to brighten the color of the waffle samples, which was associated with an increase in the b* value in samples containing 0.25–1% xanthan gum. This finding was supported by Preichardt et al. (2011), who discovered that the addition of xanthan gum increased the lightness of gluten-free cakes. However, this result contradicted the findings of Rakkhumkaew et al. (2019), who reported that the inclusion of xanthan gum resulted in darker Riceberry bread colors, which could have been due to differences in the bakery products and processes, as well as the cooking times. The use of xanthan gum greatly reduced the redness and yellowness of the crust color (Table 3). These findings were consistent with those of Esfandiary et al. (2021), who utilized xanthan gum in the development of low-fat cupcakes and reported that xanthan gum reduced crust yellowness and redness significantly. They also reported a beneficial influence on porosity, stiffness index and crust color browning, which could improve sensory attributes and increase the shelf-life of cupcakes (Esfandiary et al., 2021).

The addition of xanthan gum brightened the color of the crust and crumbs of the pancakes, which was attributable to xanthan gum increasing water holding and absorption in the matrix, resulting in a thicker mixture and the distribution of Riceberry flour color pigment (dark-purple color from anthocyanins) throughout the waffle and pancake samples. As a result, the xanthan gum improved the color brightness of the waffle and pancake samples. However, there was no significant variation in the color of the pancake crust between the two samples (0% and 2% xanthan gum addition), perhaps because the amount of xanthan gum added increased the viscosity and thickness of the batters. The addition of 2% xanthan gum contributed to the lowest spread ratio (Table 2). As the time of heating exposure for all samples was equal, the lowered surface area of batter during pan-frying than for the other samples, resulted in a darker crust color.

Table 3 Color of waffles and pancakes made with five different levels of added xanthan gum (n = 3)

Xanthan gum addition (% weight per weight of dry ingredient)	L*	a*	b*
Waffle			
0 (control)	30.48±0.16^{c}	11.67±0.02^{a}	14.95±0.15^{d}
0.25	35.76±0.19^{a}	10.58±0.13^{c}	15.59±0.06^{c}
0.5	35.36±0.37^{ab}	11.50±0.28^{a}	17.56±0.20^{a}
1	35.20±0.17^{b}	10.86±0.04^{b}	16.77±0.08^{b}
2	35.36±0.09^{ab}	10.55±0.13^{c}	14.43±0.10^{e}
Pancake (Crust color)			
Xanthan gum addition (% weight per weight of dry ingredient)	L*	a*	b*
0 (control)	35.25±0.07^{d}	15.28±0.21^{a}	28.70±0.84^{a}
0.25	43.56±0.24^{a}	11.16±0.76^{b}	26.29±2.09^{c}
0.5	40.77±1.03^{c}	11.65±0.20^{b}	26.03±0.13^{c}
1	41.65±0.12^{b}	11.61±0.07^{b}	27.01±0.54^{b}
2	34.92±0.02^{d}	11.78±0.07^{b}	20.98±0.13^{d}
Pancake (Crumb Color)			
Xanthan gum addition (% weight per weight of dry ingredient)	L*	a*	b*
0 (control)	24.88±0.68^{e}	6.89±0.15^{a}	9.60±0.42^{b}
0.25	41.24±0.37^{a}	5.95±0.10^{b}	11.29±0.26^{a}
0.5	38.85±0.28^{b}	7.07±0.21^{a}	11.85±1.11^{a}
1	36.25±0.16^{c}	6.77±0.13^{a}	8.87±0.13^{b}
2	34.79±0.03^{d}	5.87±0.08^{b}	7.84±0.03^{c}

Mean ± SD in same column superscripted by different lowercase letters are significantly (p < 0.05) different.

Table 4 Moisture content and water activity value of instant mix, waffles and pancakes with five different levels of added xanthan gum (n = 3)

Xanthan gum addition	Moisture content (%)			Water activity value		
(% weight per weight of dry ingredient)	Instant mix	Waffle	Pancake	Instant mix	Waffle	Pancake
Control	6.80±0.28^{a}	25.43±0.41^{b}	28.41±0.51^{d}	0.56±0.01^{c}	0.87±0.01^{b}	0.89±0.01^{c}
0.25	7.41±0.21^{a}	31.48±1.28^{a}	32.91±1.10^{c}	0.62±0.00^{a}	0.90±0.00^{a}	0.91±0.00^{b}
0.5	6.89±0.56^{a}	32.59±0.06^{a}	31.44±0.94^{c}	0.50±0.00^{d}	0.91±0.01^{a}	0.90±0.00^{b}
1	7.16±0.66^{a}	31.14±1.17^{a}	35.50±0.44^{b}	0.59±0.01^{b}	0.90±0.00^{a}	0.92±0.02^{ab}
2	7.26±0.28^{a}	32.68±0.22^{a}	37.79±1.90^{a}	0.59±0.00^{b}	0.91±0.00^{a}	0.93±0.00^{a}

Mean ± SD in same column superscripted by different lowercase letters are significantly (p < 0.05) different.

Effects of xanthan gum on texture profile of waffles and pancakes

The texture of the waffles was determined using the TPA method, as shown in Fig. 1; the addition of 0.25%, 0.5% or 1% xanthan gum decreased the hardness, chewiness, gumminess, and shear force (cutting force) of the waffle while significantly increasing the springiness of the waffle compared to the control. These findings were consistent with Sumnu et al. (2010), who reported that adding xanthan gum and guar gum to rice flour cake products reduced the hardness and increased the springiness of the cake because the mixture could retain more moisture than a rice flour mixture without xanthan gum and guar gum. On the other hand, the textural profile of the waffle with 2% xanthan gum addition was similar to the control sample. The inclusion of xanthan gum absorbed and retained more water in the batter mixture. As a result, the mixture thickened and got stickier. During cooking, the heat evaporated water in the batter mixture and the air bubbles were dispersed and trapped in the batter due to the viscosity. As a result, when the batter was cooked in the waffle maker, the trapped air bubbles created a softer and springier waffle. However, using an excessive amount of xanthan gum increased the viscosity of the batter which increased moisture retention, resulting in the elimination of air bubble formation during the cooking process. Hence, the waffles had a dense crumb texture and strong crust, as shown in Fig. 1. These results showed that the higher viscosity of batter with 2% xanthan gum addition resulted in a denser, harder batter. In addition, the results showed that increasing the xanthan gum increased the springiness of the waffle. However, xanthan gum additions of 1% or 2% resulted in less springiness than for 0.5% addition.

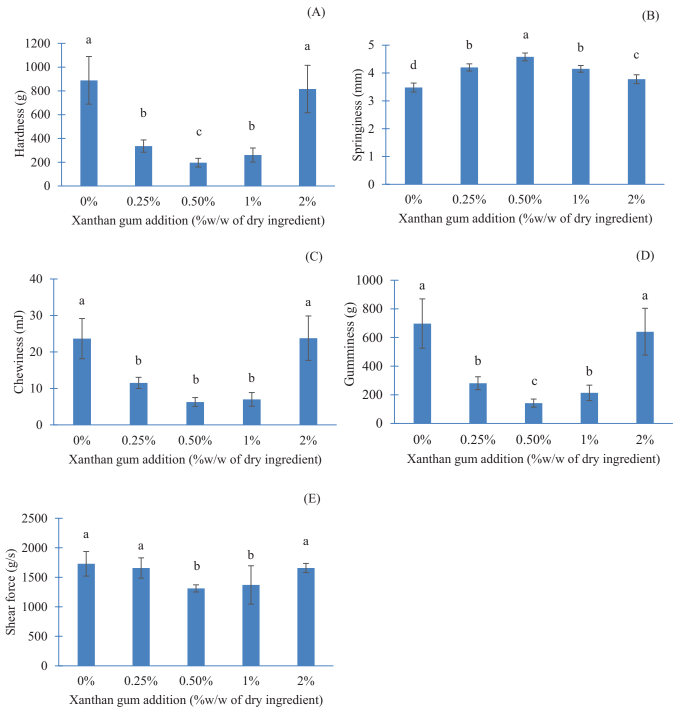

Fig. 1 Texture profile of waffles: (A) hardness; (B) springiness; (C) chewiness; (D) gumminess; (F) shear force, where values are shown as mean ± SD (n = 5), different lowercase letters above bars indicate significant ($p < 0.05$) differences and w/w = weight per weight

Furthermore, increasing the xanthan gum addition to 0.5% lowered the gumminess and chewiness of the waffle, whereas higher xanthan gum additions (1% or 2%) contributed to higher gumminess and chewiness (Figs. 1C and 1D) due to the batter's higher viscosity, which also enhanced the hardness of the waffle. This was consistent with the results for sponge cake with the addition of xanthan gum, which increased the density of the batter, resulting in decreased volume and increased stiffness of the cake (Noorlaila et al., 2020). Another study on the effect of xanthan gum on steamed Riceberry rice cake revealed that xanthan gum was a significant factor that favorably improved the products' hardness, adhesiveness, cohesion and gumminess (Laokuldilok et al., 2022). Furthermore, a study on enhancement of the physical qualities of gluten-free steamed rice cake found that adding xanthan gum enhanced the apparent viscosity of batter, contributing to a softer texture of rice cake after 4 d of storage compared to control samples (Itthivadhanapong et al., 2016). Consequently, the water-retention capabilities of xanthan gum might benefit the texture. The optimum amount added could improve the overall like and texture acceptance in terms of the hardness, adhesiveness and gumminess of cake products.

The shear force is the force required to cut a pancake into two pieces. This was measured only for pancake texture analysis since the pancake samples were not acceptable for TPA analysis because the thickness of control pancakes with 0.25% xanthan gum addition was too thin (0.3–0.4 cm) and was not suitable for probe usage for compression. As shown in Fig. 1, the pancake cutting force exhibited a similar tendency to that of the waffle samples; as the xanthan gum addition increased from 0.25% to 1%, the shear force decreased, then increased to a value equivalent to the control with 2% xanthan gum addition. The decrease in shear force was mostly associated with the density of the pancakes. This result reflected the pancake's hardness. The shear force of the control pancake was enhanced since it lacked the xanthan gum that retained water molecules, resulting in a high batter spread ratio, which increased the surface area exposed to heat and caused water to evaporate more quickly than in the other formulas. As a result, the retained moisture was lower, which increased the hardness of the pancake. The pancakes got softer with increasing (0.25%, 0.5% and 1%) xanthan gum addition and the shear force increased with 2% xanthan gum addition because the high viscosity of the batter resulted in a much thicker pancake, leading to the increased shear force, as shown in Fig. 2. Hence, the appropriate amount of xanthan gum addition was critical to achieve the desired waffle and pancake texture.

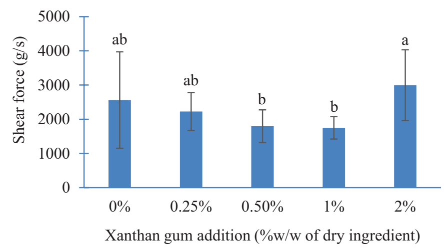

Fig. 2 Shear force of pancakes, where values are shown as mean ± SD (n = 5), different lowercase letters above bars indicate significant ($p < 0.05$) differences and w/w = weight per weight

Moisture content and water activity value of instant mix, waffles and pancakes

The addition of xanthan gum in the mix enhanced the moisture absorption and water activity values of the waffle and pancake samples, as shown in Table 4. The addition of 2% xanthan gum resulted in the maximum moisture content in the waffle and pancake samples, whereas the control sample had the lowest. The water activity value of the instant mix, waffle and pancake samples followed the same trend as the moisture values, with increases following the addition of more xanthan gum. The instant mix samples of all formulations had water activity values that was less than 0.6, which indicated that they could be stored at room temperature with a shelf life of 1–3 mth (Mohos, 2016).

Sensory evaluation

These results revealed that the acceptance scores of waffles with xanthan gum were considerably higher than for the control in terms of appearance, texture, flavor and overall acceptability (Fig. 3A). Waffles containing 0.5% xanthan gum obtained the greatest overall acceptance. For pancakes, the control and 2% xanthan gum addition produced similar results for all criteria. However, the pancake samples with 0.25–1% xanthan gum added had higher acceptance scores than the control in terms of appearance, color, texture, flavor and overall acceptability. As demonstrated in Fig. 3B, the pancake samples with 0.5% xanthan gum addition had the highest acceptance score for every attribute because the xanthan gum addition (0.5%) absorbed water and retained moisture in the products that helped to improve the texture by decreasing the hardness and increasing the springiness of the products and improving the physical properties in terms of appearance and color, as well as improving the flavor. These results were confirmed by Kalajahi (2021), who reported that 0.5% xanthan gum enhanced the sensory qualities of eggless cake samples by increasing the moisture content and decreasing the stiffness. A suitable amount of added xanthan gum resulted in a considerable rise in the acceptability score; however, an excessive amount of added xanthan gum resulted in unfavorable impacts on waffles and pancakes.

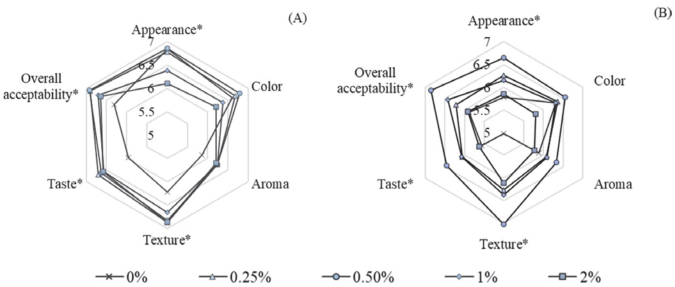

Fig. 3 Effect of different levels of xanthan gum addition (0–2%) on: (A) acceptability of waffles; (B) acceptability of pancake samples, where * indicates significant ($p < 0.05$) differences within each attribute (n = 50)

Proximate composition of instant mix, waffles and pancakes

Based on the sensory acceptability, physical attributes and textural quality, the waffles and pancakes with 0.5% xanthan gum addition were chosen as the final products to be examined for proximate analysis and comparison with the control. This was due to the fact that 0.5%xanthan gum addition improved the quality of waffles and pancakes which enhanced these products so that they gained the highest acceptability scores, especially regarding appearance texture and taste. The chosen Riceberry instant mix had moisture, ash, fat, protein and carbohydrate concentrations of 6.22 g/100 g dry matter, 2.76 g/100 g dry matter, 1.59 g/100 g dry matter, 5.36 and 83.81 g/100 g dry matter, respectively. The instant mix with 0.5% xanthan gum had slightly lower moisture and fat contents than the control, as indicated in Table 5. However, the protein, fat and fiber components were not substantially different. As a result of the xanthan gum addition, which reduced the moisture level of the mix, the carbohydrate and energy contents of the mix were slightly higher than for the control.

The proximate compositions of the waffles and pancakes are shown in Table 5. As a result of the increased moisture content, the carbohydrates and energy in the waffle and pancake samples were lower than in the control. The addition of 0.5% xanthan gum to the waffle and pancake mixtures was suitable regarding sensory, physical and textural features. The use of xanthan gum was observed to have a protective effect on anthocyanin stability, which was beneficial for this Riceberry instant mix for waffles and pancakes in terms of color stability and the antioxidant property in the products that should be researched further (Zhao et al., 2021). Furthermore, numerous studies have demonstrated that adding xanthan gum to food items improves the glycemic response. For example, long-term intervention research discovered that ingesting xanthan gum muffins for 6 wk might reduce the glycemic load by 31% and increase satiety without causing stomach symptoms (Osilesi

Table 5 Proximate composition of instant mix, waffles and pancakes of control and formula with 0.5% added xanthan gum (n = 3)

Proximate composition/ Xanthan gum addition (% weight per weight of dry ingredient)	Instant mix		Waffle		Pancake	
	0% (Control)	0.5%	0% (Control)	0.5%	0% (Control)	0.5%
Moisture	7.69±0.23[a]	6.22±0.03[b]	25.43±0.41[a]	32.59±0.06[b]	28.41±0.51[a]	31.44±0.94[b]
Protein	1.40±0.12[a]	1.59±0.28[a]	5.66±0.72[a]	6.56±0.43[a]	4.02±0.12[a]	4.45±0.11[b]
Fat	3.78±0.56[a]	2.76±0.09[b]	9.44±0.19[a]	9.28±0.67[a]	4.07±0.84[a]	4.30±1.09[a]
Ash	5.31±0.18[a]	5.36±0.28[a]	2.17±0.07[a]	2.01±0.07[a]	1.87±0.02[a]	1.90±0.21[a]
Fiber	0.29±0.06[a]	0.26±0.03[a]	1.13±0.05[a]	1.01±0.16[a]	1.07±0.06[a]	0.88±0.19[a]
Carbohydrate	81.53	83.81	56.17	48.55	60.56	57.03
Total energy (kcal per 100 g)	365.74	366.44	332.28	303.96	294.95	284.62

Mean ± SD in same row within each category (instant mix, waffle or pancake) superscripted by different lowercase letters are significantly ($p < 0.05$) different.

et al., 1985). Fuwa et al. (2016) found a substantial reduction in postprandial hyperglycemia 15 min and 30 min after eating cooked rice with 1−2 % xanthan gum added during and after cooking. Tanaka et al. (2018) discovered that xanthan gum in an enteral formula reduced the area under the curve glucose by 48%, indicating that it may prevent or decrease glucose digestion and absorption, which could enhance the health advantages of gluten-free products. Furthermore, Naharudin et al. (2020) reported a substantial reduction in appetite and an increase in fullness after eating a semi-solid breakfast with added xanthan gum. This influence on appetite might also be advantageous to some people's health. However, because of the complexity of each food product, the effect of xanthan gum in each food matrix on the glycemic response and appetite may vary. As a result, research on this impact should be done to explore the health advantages of each combination of xanthan gum and food product.

It was challenging to make a high-quality waffle and pancake with gluten-free Riceberry flour. When the proper amount of xanthan gum was added to the flour mix prepared from Riceberry flour for the pancakes and waffles, the moisture content of the pancakes and waffles increased. As a result of the properties of hydrocolloids (that can mimic the gluten property by binding with water and forming a structure that can retain constant gas bubbles in waffle and pancake products), the samples had a softer texture (greater springiness and lower hardness). The addition of 0.5% xanthan gum to the waffle and pancake mixes was sufficient to improve the physical, chemical and sensory qualities of these products. The current study provided a solution to the quality problems of gluten-free products, as well as an alternative to enhance the usage of Riceberry flour, which is a healthy complex carbohydrate and a great source of antioxidants.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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