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Substitution of rice flour with banana flour for developing Khanom Thong Att products

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Abstract

Khanom Thong Att (Thai style crispy crackers made from flours, sugar, eggs, water, and coconut milk) is one of the favourite desserts among Thai people and foreigners, However, for health-conscious people, Khanom Thong Att with wheat flour or rice flour as its main ingredient may not be a good choice. Conversely, banana flour is a good source of bioactive compounds, antioxidants, and resistant starch. Therefore, the purpose of this research was to study the substitution of rice flour with banana flour to develop Khanom Thong Att products. Banana flour was prepared based on the Dangsungwal method. Three basic formulas were studied, and the appropriate basic formula was used to study the consumption of banana flour. There were five levels of banana flour 20, 40, 60, 80, and 100%, respectively. The sample with 100% banana flour was found the most suitable formula to produce the final product which was further studied in terms of physical and chemical properties. It was found that moisture, protein, fat, carbohydrates, fibre, and ash were 5.15, 4.28, 3.06, 81.88, 1.57, and 3.41%, respectively. While water activity (aw), colour (L^*, a^* and b^*), total phenolic content, and antioxidants activity were 0.27, 56.63, 13.05, 19.23, 94.53, and 16.65 mg/100 g, respectively. For the sensory evaluation, Khanom Thong Att substituted with 100% banana flour had the highest preference score.

1. Introduction

Kluai Namwa (Namwa Banana, *Musa sapientum L.*, or *Musa AAB cv.*) is an easy and fast-growing plant that can be cultivated all year round in every region of Thailand with an annual output of approximately 2 million tons. The names used are also different, for instance, Kluai Mali Ong (Chanthaburi), Kluai Tai (Chiang Mai, Chiang Rai), Kluai Ong (Chaiyaphum) Kluai Tani Ong (Ubon Ratchathani). However, bananas are fruits that have a high breathing rate after harvesting (climacteric fruit). Hence, they ripe quickly. As they ripen, the peel shows black spots and they fall off the bunch easily. Short shelf life and easy spoilage can lead to price deterioration. However, ripe banana fruits remain highly nutritious and energy-rich because during ripening the starch in the banana fruit turns into sucrose, fructose, and glucose which are easily absorbed sugars. It contains high amounts of pectin and cellulose fibre. Ripe bananas can also be processed into high-value food products (Phuapisit *et al*., 2016; Ng *et al*., 2020). Banana flour can be considered a product of processing natural raw materials with glycemic value. The consumption of bananas or banana flour can help prevent diabetes, cancer, obesity, and heart disease. In addition, banana flour has a unique smell. It has physical properties that are well combined with water. When heated, it inflates transparently. When left cold, it looks like jelly, as amylase helps to decompose high-starchy foods. It has been reported that banana flour contains phenolic compounds, which have many antioxidant effects (Vergara-Valencia *et al*., 2007; Floegel *et al*., 2011; Singh *et al*., 2016). Being high in fibre and prebiotics helps people digest and balance the gastrointestinal tract (Faisant and Champ, 1995).

There are a variety of Thai desserts. All of which are unique, colourful, and flavoursome. The main ingredients of Thai desserts are flour, sugar, and coconut. Several Thai desserts require exquisite skills as well as extended care and time while preparing, and numerous desserts with meaningful names are used in rituals and ceremonies. Many names of desserts include the word Thong, meaning gold and signifying prosperity and glory (Amazing Gastronomy of Thailand, 2021). Khanom Thong Att has earned a high reputation in Thailand and

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beyond. Nevertheless, as its main ingredient is wheat flour or rice flour, health-conscious consumers may not be interested in it. Banana flour is then taken into account to make Khanom Thong Att become a healthier choice because it is more nutritious than other flours, namely cassava starch, corn starch, and tapioca starch. It is also an ingredient for producing gluten-free bakeries (Wang *et al*., 2012). Therefore, the objective of this study was to develop Khanom Thong Att products by using banana flour instead of wheat flour or rice flour and to create new healthy products for consumers which can also create added value for agricultural produce.

2. Materials and methods

2.1 Preparation of raw materials

The ingredients for making Khanom Thong Att products including ripe bananas, unripe bananas, rice flour, wheat flour, sugar, chicken eggs, salt, and black sesame seeds were purchased from a local market in Pathum Thani, Thailand.

2.2 Preparation of banana flour

Unripe banana flour was prepared using the procedure described by Dangsungwal (2009). Unripe bananas were washed and boiled in boiling water for 5 mins. Then, they were cooled immediately with cold water. Fruits were peeled and cut into 3 mm slices. Then, they were soaked in sodium metabisulfite (0.1% w/v) which was adjusted to pH 3.3 using citric acid. The slices were dried at 60°C for 4 hrs. After that, the dried bananas were ground by a grinder and sifted through a 100 mesh sieve. Their moisture content and quantity of a_w were analyzed. Finally, the sample was stored at 4°C in aluminium foil bags for further analysis.

2.3 Development of Khanom Thong Att products

2.3.1 Preparation of basic formulas

To come up with the basic formula for producing Khanom Thong Att products, three formulas were experimented with (Table 1). All dry ingredients were mixed. Then, ripe bananas, eggs, water, and coconut milk were added. One spoon of the sample was dropped on the stove at 150°C for 2 mins. The sensory evaluation in terms of appearance, taste, texture, and overall preferences was conducted with 100 untrained panellists by means of a 9-point hedonic scoring test (Wiriyacharee, 2002).

Table 1. Study the basic formulas of Khanom Thong Att

Raw material (g)	Formula 1	Formula 2	Formula 3
Rice flour	130	0	0
Wheat flour	0	70	70
Ripe banana	150	0	0
Sugar	50	40	50
Chicken egg	50	0	0
Duck egg	0	60	60
Salt	4	2	2
Black sesame	5	0	0
Coconut milk	0	125	125
Water	90	0	0
Limewater	0	20	0

2.3.2 Development of Khanom Thong Att from banana flour

The basic formula obtained from section 2.3.1 was used to determine the proper content of banana flour used to substitute the content of rice flour. The contents of banana flour used were 20, 40, 60, 80, and 100% of the rice flour weight used while other ingredients remained the same (Table 2). The moisture content of the sample was determined after being dried at 105°C until a constant weight was attained (AOAC, 2005). A_w was determined by AOAC (2005) method (Novasina, Pfäffikon, Switzerland). The colour of the sample was measured using a colourimeter (CR-400, Konica Minolta, Japan). The obtained values were placed in the CIE colour profile system as L^* value (lightness), a^* value (redness/greenness), and b^* value (yellowness/ blueness) and recorded (Hamzah, 2021). The sensory evaluation by means of a 9-point hedonic scoring test (Wiriyacharee, 2002) was conducted in terms of appearance, taste, texture, and overall preferences with 100 untrained panellists.

2.4 Physicochemical properties and sensory characteristics

The sample of Khanom Thong Att obtained from

Table 2. Replacing rice flour with and without banana flour in Khanom Thong Att

Raw material (g)	Banana flour content (%) (based on rice flour weight)					
	control	20	40	60	80	100
Rice flour	130	104	78	52	26	0
Banana flour	0	26	52	78	104	130
Ripe banana	150	150	150	150	150	150
Sugar	50	50	50	50	50	50
Chicken egg	50	50	50	50	50	50
Salt	4	4	4	4	4	4
Black sesame	5	5	5	5	5	5
Water	90	90	90	90	90	90

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section 2.3.2 was analyzed regarding physicochemical properties and sensory characteristics. The chemical compositions of rice samples were analyzed according to AOAC (2005) standard methods. The moisture content of the rice sample was determined after being dried at 105°C until a constant weight was attained. Protein was determined by combustion (LEGO EP-528, United States). Crude lipids were extracted with petroleum ether, using a soxhlet extraction unit (Tecator A Perstorp Analytical Company, Sweden). Ash and fibre contents were determined using gravimetric methods. The total crude carbohydrate was estimated by equation (1).

Carbohydrate (%) = 100 - (%moisture + %protein = % lipids + % fibre + %ash) (1)

Total phenolic content was extracted following the method of Waterman and Mole (1994). Approximately 1 g of ground pigmented rice sample was extracted with 10 mL of 80% methanol diluted with distilled water. The mixture was continuously shaken for 30 mins at room temperature, and the sample mixture was passed through the filter paper (Whatman No. 4). Approximately 1 mL of filtered solution was mixed with 5 mL of 10% Folin-ciocalteu reagent in distilled water and shaken for 8 mins. After that, 4 mL of 7.5% Na_2CO_3 in distilled water was added. The final mixture was left for 120 mins before reading the absorbance at 765 nm using a UV-visible spectrophotometer (UV WinLab, Perkin Elmer, Thailand). The data were expressed as mg gallic acid equivalents (GAE)/g dry matter, based on the calibration curve of gallic acid.

The antioxidative activities were determined in terms of 2,2-diphenyl-1-picrylhydrazyl radical (DPPH), and 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) radical scavenging activities. Approximately 1 g of ground pigmented rice sample was extracted with 10 mL of methanol, and the mixture was continuously shaken for 60 mins at room temperature. DPPH radical scavenging activity was modified using the method of Mahattanatawe *et al*. (2006). Approximately 2 mL of DPPH (1.0 mM in methanol) was mixed with 3 mL of all of the extracted solution in water at different concentrations. The mixture was kept at room temperature in darkness for 30 mins prior to measurement of the absorbance at 517 nm using a UV-visible spectrophotometer (UV WinLab, Perkin Elmer, Thailand). Lower absorbance values of the reaction mixture indicated higher free-radical-scavenging activity. The capability to scavenge the DPPH radical was calculated using the following equation (2):

DPPH scavenging effect (%) = (A0 –A1/A0) ×100 (2)

Where A0 is the absorbance of the control reaction (DPPH radical + methanol) and A1 is the absorbance of the presence of all of the extract samples and standard (DPPH radical + sample extract/standard).

2.5 Statistical analysis

The experiment was carried out using a complete randomized design (CRD) with 3 replications. Measurements were conducted in triplicates. The results were statistically analyzed by one-way ANOVA technique using SPSS and Duncan's multiple range test was used to determine significant differences between mean values. Statistical significance was declared at a 95% confidence level ($p \leq 0.05$).

3. Results and discussion

3.1 Physical characteristics of banana flour

An analysis result of the quality of the banana flour which is the major ingredient used in the production of Khanom Thong Att with moisture content and quantity of a_w were 7.03 and 0.37%, respectively. This is in accordance with one of the requirements established by the Standards for Community Products; the product moisture shall not exceed 12% (Standards for Community Products, 2007). There was a study conducted on substituting banana flour for rice flour in large flat noodles. The chemical composition of the banana flour was analyzed before testing. Moisture, protein, fat, ash, fibre, and carbohydrates found in the banana flour were 4.36, 2.80, 1.06, 2.23, 1.65, and 87.9%, respectively. The banana flour produced has a high carbohydrate content, so it can be used as a substitute for rice flour in the production of large flat noodles (Aussawasathein and Nilnate, 2005). In addition, there was another study aiming to develop crispy brownies by using banana flour instead of wheat flour. It was found that banana flour contained moisture content, protein, fat, ash, fibre, and carbohydrates at 1.05, 5.50, 21.96, 2.40, and 69.10%, respectively (Khummee *et al*., 2017)

3.2 Physicochemical properties and sensory characteristics of Khanom Thong Att product

To obtain the proper formula for Khanom Thong Att, three formulas were analyzed based on the sensory evaluation (Table 3). It revealed that there was no statistically significant difference in appearance preference scores among the three basic formulas ($p>0.05$). Meanwhile, there were statistically significant differences in taste, texture, and preference ($p \leq 0.05$). The scores of appearance, taste, and overall preference ranged from 5.40-6.70, 5.70-6.90, 6.20-7.00 and 5.90-7.10, respectively. Considering their preferences, the first formula received the highest score in all aspects. Therefore, it was selected as the suitable formula to study in the next step. The panellists preferred the

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formula with ripe bananas to the one without them. This may be due to the fact that they liked the smell and taste of ripe bananas (Ng *et al*., 2020).

Table 3. Sensory evaluation of Khanom Thong Att

Quality	Formula 1	Formula 2	Formula 3
Appearance	6.70±0.48[a]	6.50±0.53[a]	5.40±0.52[a]
Taste	6.90±0.57[a]	6.00±0.67[b]	5.70±0.68[b]
Texture	7.00±0.67[a]	6.20±0.63[b]	6.20±0.42[b]
Overall	7.10±0.62[a]	6.20±0.42[b]	5.90±0.57[b]

Values presented are means±standard deviations. Values with different superscripts within the same row are significantly different at 95% confidence level (p≤0.05).

When analyzing the physical and chemical properties of the products (Table 4) by using the amount of banana flour instead of rice flour compared with the control sample, it was found that all 5 formulas of Khanom Thong Att had moisture content and quantity of a_w in the range of 4.62-6.80 and 0.22-0.30%, respectively. By substituting banana flour for rice flour, the moisture and a_w value of the sample significantly decreased (p≤0.05), compared with a control sample with the content of banana flour at 40, 60, 80, and 100%. However, the moisture values specified by industry product standards should not exceed 6% (Standards for Community Products, 2006). These results correspond to Chong and Noor Aziah (2008) who substituted banana flour as a partial replacement for wheat flour in doughnuts. This is because substituted banana flour produces lower moisture content during high-heat processing. Meanwhile, the a_w value of all samples was below 0.60 which can inhibit the growth of microorganisms (Rattanapano, 2014; Pornchalermpong and Rattanapano, 2021). The colour value of the 5 formulas of the products revealed that the lightness (*L**) was in the range of 59.33-64.98, the redness (*a**) 8.87-12.56, and the yellowness (*b**) 19.59-23.86, respectively. The increased quantity of the banana flour resulted in a decrease in *L** (p≤0.05) while *a** value increased (p≤0.05). Meanwhile, the *b** value showed no statistically significant difference (p>0.05). The results of the experiments were similar to the study on using banana flour to replace wheat flour in the Kleap Lamduan products (Lamduan flower shortbread cookie) (Manarote *et al*., 2018). It was found that the banana flour substitution level was higher. As a result, the *L** value decreased, but *a** value tended to increase, while the *b** value was not different from the control sample (Poonloon *et al*., 2014). This may result from the heating effect which darkens the sample to be dark brown.

Regarding the sensory testing of all 5 formulas of Khanom Thong Att products (Table 5), it revealed that the panellists statistically significantly preferred appearance, taste, texture, and the overall preference (p≤0.05) compared with the control formula. The sample with 100% banana flour substitution received the highest average preference scores. The scores given on appearance, taste, texture, and overall were 7.00, 6.95, 7.00, and 7.25, respectively. The results showed that panellists preferred the sample with the highest level of banana starch content. Dangsungwal *et al*. (2009) studied the use of banana flour to substitute wheat flour in brownies. It was found that 50% banana flour substitution for wheat flour gained the highest overall sensory scores, compared with the control sample. Furthermore, Poonloon *et al*. (2014) replaced wheat flour with banana flour in Khanom Kleap Lamduan products and found that the replacement of banana flour at 15% in the sample had the highest overall sensory scores.

Table 4. Physical and chemical properties of 5 formulations of Khanom Thong Att products

Quality	Banana flour content (%) (based on rice flour weight)					
	Control	20	40	60	80	100
Moisture content (%)	8.41±0.04[a]	6.80±0.08[b]	5.80±0.15[c]	4.62±0.14[d]	4.63±0.03[d]	4.72±0.07[d]
a_w	0.35±0.01[a]	0.30±0.01[b]	0.27±0.01[c]	0.25±0.02[d]	0.25±0.01[d]	0.22±0.01[e]
*L**	65.15±0.36[a]	64.98±0.24[a]	64.77±0.26[a]	61.83±0.86[ab]	61.48±0.94[ab]	59.33±1.18[b]
*a**	5.53±0.89[c]	9.60±0.87[ab]	8.87±0.16[b]	12.29±0.29[a]	12.56±0.21[a]	11.04±0.15[ab]
*b**	20.52±0.38[a]	22.71±0.15[a]	19.59±0.26[a]	21.01±0.14[a]	23.86±0.30[a]	22.68±0.17[a]

Values presented are means±standard deviations. Values with different superscripts within the same row are significantly different at 95% confidence level (p≤0.05).

Table 5. Sensory evaluation of 5 formulations of Khanom Thong Att products

Quality	Banana flour content (%) (based on rice flour weight)					
	Control	20	40	60	80	100
Appearance	6.20±0.42[ab]	5.90±0.39[c]	6.30±0.48[ab]	6.25±0.43[ab]	6.40±0.52[b]	7.00±0.67[a]
Taste	6.60±0.52[ab]	6.10±0.74[b]	6.10±0.74[b]	6.30±0.68[ab]	6.40±0.70[ab]	6.95±0.69[a]
Texture	6.30±0.48[b]	6.25±0.43[b]	6.40±0.52[b]	6.40±0.70[b]	6.70±0.48[ab]	7.00±0.67[a]
Overall	6.60±0.52[b]	6.20±0.79[b]	6.30±0.48[b]	6.35±0.67[b]	6.55±0.60[b]	7.25±0.72[a]

Values presented are means±standard deviations. Values with different superscripts within the same row are significantly different at 95% confidence level (p≤0.05).

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Considering the results on the physicochemical properties and sensory characteristics, the formula with 100% banana flour substitution was selected for further analysis regarding the final product quality and important antioxidant effects.

3.3 The results on final product quality

Khanom Thong Att was analyzed in terms of physical and chemical properties (Table 6). The total energy value was found to be 358.55 kcal while the recommended daily energy intake should not exceed 2,000 kcal/day (Food and Drug Administration Ministry of Public Health, 2021). The moisture content was 5.15% which complied with the standard. However, the samples with greater than 14% moisture content could affect the flour quality over storage periods (Bakare *et al*., 2017). The quantities of protein, fat, carbohydrate, fibre and ash content were 4.28, 3.06, 81.88, 1.57, and 3.41%, respectively. The value of a_w was 0.27. However, the amount of water activity can affect the growth of microorganisms. The free water content of less than 0.7 can inhibit the growth of microorganisms (Breene *et al*., 1988). This was in line with other studies' findings which revealed that products with less than 0.5 water activity content were classified as microbial free products (Beuchat, 1981). The colour values (L^*, a^* and b^*) were 56.63, 13.05, and 19.23, respectively. The total amounts of phenolic content and antioxidant activity (DPPH) were 94.53 and 16.65 mg/100 g, respectively. It has been reported that the antioxidants found in bananas belong to the group of phenolic compounds including catechin, epicatechin, lignin, and tannin. There are also other groups of substances that have antioxidant activity, such as vitamin C, vitamin E, and beta-carotene. (Sulaiman *et al*., 2011; Alkarkhi, 2011). Varieties of bananas and components of banana fruit, such as peel and pulp also affect the antioxidant activity and phenolic compounds (Fatemeh *et al*., 2012; Vatanasuchart *et al*., 2012). From sensory evaluation (Table 7), the test subjects rated the appearance, taste, texture, and overall liking of 7.12, 7.56, 7.65, and 7.45, respectively.

Table 6. Quality analysis of the final product

Quality	Khanom Thong Att product (100 g)
Total energy (kcal)	358.55±0.01
Moisture (%)	5.15±0.08
Protein (%)	4.28±0.02
Fat (%)	3.06±0.20
Carbohydrate (%)	81.88±0.01
Fibre (%)	1.57±0.09
Ash (%)	3.41±0.06
a_w	0.27±0.01
L^*	56.63±1.85
a^*	13.05±1.09
b^*	19.23±1.17
Total phenolic (mg/100 g)	94.53±0.79
Antioxidant activity (DPPH) (mg/100 g)	16.65±0.45

Table 7. Sensory evaluation of final product

Quality	Khanom Thong Att product (100 g)
Appearance	7.12±0.87
Taste	7.56±0.88
Texture	7.65±0.82
Overall	7.45±0.93

Values presented are means±standard deviations.

4. Conclusion

The study on the banana flour content for developing Khanom Thong Att products included selecting the proper formulation and evaluating the quality of the developed products. The findings revealed that banana flour, which was used as the main ingredient in the production of Khanom Thong Att in this study, had moisture and the a_w value in accordance with a recognized standard. The basic formula with ripe bananas was selected by the panellists. Therefore, it was further analyzed. Five levels of banana flour substitution (20, 40, 60, 80, and 100%) were used. The 100% banana flour substitution for rice flour gained the highest preference scores from the sensory evaluation while having moisture and the a_w value complying with a recognized standard. The total amounts of phenolic content and antioxidant activity (DPPH) were 94.53 mg/100 g and 16.65 mg/100 g, respectively. Consequently, the use of 100% banana flour in compressed Khanom Thong Att has been selected as the end product. Khanom Thong Att with banana flour substitution for rice flour not only expands consumers' healthy food choices but also increases the value of agricultural produce.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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