RESEARCH ARTICLE

Enhancing Bioactive Compounds and the Antioxidant Properties of Thai Coconut Pancake (Khanom Ba-bin) through Partial Substitution with Thai Pigmented Rice Flours

Chaiyasit Punfujinda[1], Rath Chombhuphan[2], Sermsri Songnearm[2], Sawai Boukaew[3], Poomipong Tula[4], Korawit Sakkaekaew[4] and Krittin Chumkaew[1,*]

[1]Department of Food and Nutrition, Faculty of Home Economics Technology, Rajamangala University of Technology, Thanyaburi, Pathum Thani 12110, Thailand; [2]Department of Creative Arts Innovation, Faculty of Home Economics Technology, Rajamangala University of Technology, Thanyaburi, Pathum Thani 12110, Thailand; [3]Faculty of Agricultural Technology, Songkhla Rajabhat University, Songkhla, 90000, Thailand; [4]Major of Culinary Arts, Faculty of Culinary Arts, Dusit Thani College, Bangkok 10250, Thailand

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Abstract: ***Background:*** Thai Coconut Pancake (Khanom Ba-bin) is a traditional Thai dessert made from glutinous rice flour, coconut, and sugar. It is gaining popularity, especially as a street food in night markets. However, its nutritional value is limited due to its main ingredients.

Objective: This study aimed to develop and evaluate Thai Coconut Pancake using various Thai pigmented rice flours as partial substitutes for white glutinous rice flour to enhance its nutritional value and antioxidant properties and determine consumer acceptance through sensory evaluation.

Methods: Four pigmented rice varieties (Sung Yod, Riceberry, Hom Nil, and black glutinous rice) were used to replace white glutinous rice flour at 10%, 20%, and 30% levels. The total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activities (DPPH and ABTS assays) of the modified Thai Coconut Pancake samples were determined and compared. Sensory evaluation was conducted using a 9-point hedonic scale to assess consumer acceptance.

Results: Incorporating pigmented rice flours significantly increased TPC, TFC, and antioxidant activities compared to the control (100% white glutinous rice flour). Black glutinous rice flour substitution at 30% yielded the highest TPC (65.39 ± 0.32 µg GAE/g dw) and TFC (63.09 ± 0.56 µg QE/g dw). Hom Nil rice flour at 30% substitution exhibited the highest antioxidant activities in both DPPH (31.65 ± 0.43% inhibition) and ABTS (60.83 ± 0.45% inhibition) assays. A clear dose-response relationship was observed between substitution levels and the content in terms of bioactive compounds. Sensory evaluation revealed that a 20% substitution level was optimal, showing no significant differences in overall acceptability compared to the control, indicating the potential for product development.

Conclusion: This study demonstrates the potential of using Thai pigmented rice flours to enhance the nutritional value and antioxidant properties of traditional Thai desserts, with a 20% substitution level providing optimal balance between nutritional enhancement and sensory acceptance, offering a promising approach to developing healthier food products while preserving cultural authenticity.

Keywords: Food, Thai pigmented rice, traditional Thai dessert, bioactive compounds, antioxidant activity, Thai Coconut Pancake.

1. INTRODUCTION

Thai desserts are symbols of the country's national identity, embodying refinement in their preparation techniques, ingredients selection, and presentation [1]. They are considered a cherished cultural legacy handed down through generations [2]. Thai Coconut Pancake (Khanom Ba-bin) is one such traditional dessert made from glutinous rice flour, coconut, and sugar. It is roasted, with a heat applied from both above and below, and is commonly used in the Khan Mak procession at wedding ceremonies. The dessert originated during the Rattanakosin period, created by Auntie Bin, and

*Address correspondence to this author at the Department of Food and Nutrition, Faculty of Home Economics Technology, Rajamangala University of Technology, Thanyaburi, Pathum Thani 12110, Thailand;
E-mail: krittin_c@rmutt.ac.th

was initially called Khanom Pa-bin before its current name evolved [3]. However, being primarily made from flour, sugar, and coconut, Thai Coconut Pancake provides limited nutritional benefits. Therefore, developing it to enhance its nutritional value by incorporating, for example, Thai pigmented rice would not only benefit consumers but also help preserve this cultural dessert [1]. This modification may increase its biologically active substances and antioxidant properties.

Currently, Thai Coconut Pancake is a very popular Thai delicacy among consumers. At night markets, one may find shops selling Thai Coconut Pancake as a type of street food. The majority of Thai Coconut Pancakes available for purchase are primarily made from white glutinous rice flour, partially substituted with black glutinous rice flour. The texture of the food is characterized by its crisp outer layer and tender inside layer. This is a key feature that appeals to customers and influences their buying choices.

Rice (*Oryza sativa* L.) serves as a critical staple for over 50% of the global population, the majority of whom live in Asia [4, 5]. In Thailand, rice is the main crop. Thailand produces rice mostly for internal use but exports it as well [6]. Rice is a source of energy, vitamins, and essential trace elements for humans [7]. Pigmented rice offers numerous health benefits. This is because pigmented rice contains biologically active substances that have antioxidant properties. Nowadays, pigmented rice is becoming more popular among consumers. In addition, pigmented rice can also be used in the food industry [8]. Pigmented rice has increased in popularity among health-conscious consumers in the recent past and the color of rice is an important factor in consumer purchasing decisions [9]. Moreover, it has been found that Thai pigmented rice (*Oryza sativa* L.), especially cultivars of black, purple, and red rice such as black glutinous rice (black rice), Riceberry rice (dark purple rice), Hom Nil rice (black rice), and Sung Yod rice (red rice), is recognized as having high levels of antioxidant compounds [10]. Phenolic compounds represent a significant class of bioactive constituents found in rice. Proanthocyanidins and anthocyanins are the principal phenolic compounds found in black and red rice, respectively [11]. The predominant cause of pigmentation observed in rice is purportedly attributed to the existence of anthocyanins, which are flavonoid compounds [12]. Pigmented rice has more benefits than non-pigmented rice [9, 13] because it contains antioxidants that help reduce the chance of cell degeneration in the body, the occurrence of various diseases, and the effects of aging; they also play a role in diabetes control, the prevention of cardiovascular disease, anti-cancer effects, and anti-inflammatory effects [14-17]. Antioxidants have the capacity to form chemical bonds with free radicals, which leads to the neutralization of free radicals, preventing their interaction with other cellular entities [15, 18]. In addition, it has been found that this rice does not contain any gluten, which means it is safe for people with celiac [15].

Past research has shown that Thai pigmented rice has been adopted for use in desserts, such as by adding jasmine rice flour and Riceberry rice flour to bread products. It has been found that bread made from Riceberry rice flour is rich in anthocyanins. It can be used as an ingredient in healthy, gluten-free bread alternatives [19], and Riceberry rice flour has been used in Thai snack products (khanom pan-sib) [20]. Black glutinous rice flour has also been used instead of wheat flour in cake products [21]. Additionally, previous studies have shown that pigmented rice samples show a range of physicochemical, functional, and antioxidant traits, which means they could be used to make a wide range of health-promoting products [22]. Furthermore, this highlights the potential for Thai pigmented rice to be used and transformed into many varieties of desserts. Presently, Thai pigmented rice is processed into flour to make it more convenient and enhance its use. It is readily accessible and generally available on the market.

Therefore, it can be noted that in past research, Thai-pigmented rice flour has been used to process a variety of products. However, there is no report on the use of different cultivars of Thai pigmented rice flour to develop traditional Thai desserts and study the antioxidant activity in those desserts. This is the basis of this research, which emphasizes the importance of using Thai pigmented rice as an ingredient in Thai Coconut Pancake. The primary aim of this study is to develop and evaluate Thai Coconut Pancake using various Thai pigmented rice flours (Sung Yod rice flour, Riceberry rice flour, Hom Nil rice flour, and black glutinous rice flour) as partial substitutes for white glutinous rice flour. Specifically, the research objectives are to determine and compare the total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activities of these modified Thai Coconut Pancake samples using DPPH and ABTS assays, as well as to evaluate consumer acceptance through sensory evaluation. This research seeks to explore the potential of enhancing the nutritional value and antioxidant properties of traditional Thai desserts through the incorporation of pigmented rice flour while maintaining sensory acceptability.

2. MATERIALS AND METHODS

2.1. Raw Materials

The raw materials used in the production of Thai Coconut Pancake (Khanom Ba-bin) were as follows: Thai pigmented rice flour consisting of white glutinous rice flour (Erawan brand: Cho Heng Rice Vermicelli Factory Co., Ltd.), Sung Yod rice flour (Baan Sung Yod rice flour brand), Riceberry rice flour (B-Natural brand: Bangyai Supply Ltd.), Hom Nil rice flour (B-Natural brand: Bangyai Supply Ltd.), and black glutinous rice flour (Fancy Carp brand: Charoenworrakit, Ltd.). Additional ingredients included arrowroot flour (Dragon Fish brand: Tong Chan Juristic Person Ordinary Partnership), salt (Prung Thip brand: Refined Salt Industry Company Limited), sugar (Mitr Phol brand: Mitr Phol Sugar Corp., Ltd.), palm sugar (Mitr Phol brand: Mitr Phol Sugar Corp., Ltd.), and coconut milk (AROY-D brand: Thai Agri Foods Public Company Limited). Coconut water and young grated coconuts were purchased from a fresh market.

2.2. Formulation and Production Process for Thai Coconut Pancake

The formulations for Thai Coconut Pancake were developed based on a traditional recipe, with variations incorpo-

Table 1. Formulation of the Thai Coconut Pancake.

Ingredient (g)	1	2	3	4	5	6	7	8	9	10	11	12	13
White glutinous rice flour	240	216	192	168	216	192	168	216	192	168	216	192	168
Sung Yod rice flour	-	24	48	72	-	-	-	-	-	-	-	-	-
Riceberry rice flour	-	-	-	-	24	48	72	-	-	-	-	-	-
Hom Nil rice flour	-	-	-	-	-	-	-	24	48	72	-	-	-
Black glutinous rice flour	-	-	-	-	-	-	-	-	-	-	24	48	72
Arrowroot flour	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
Salt	3	3	3	3	3	3	3	3	3	3	3	3	3
Sugar	75	75	75	75	75	75	75	75	75	75	75	75	75
Palm sugar	113	113	113	113	113	113	113	113	113	113	113	113	113
Coconut milk	150	150	150	150	150	150	150	150	150	150	150	150	150
Coconut water	75	75	75	75	75	75	75	75	75	75	75	75	75
Grated young coconut	300	300	300	300	300	300	300	300	300	300	300	300	300

Note: Sample 1 = B-WG (Control), 2 = B-SY10, 3 = B-SY20, 4 = B-SY30, 5 = B-RB10, 6 = B-RB20, 7 = B-RB30, 8 = B-HN10, 9 = B-HN20, 10 = B-HN30, 11 = B-BG10, 12 = B-BG20, and 13 = B-BG30.

rating different pigmented rice flour. Table **1** presents the detailed ingredient compositions for each formulation, measured in grams. The control sample (B-WG) was prepared using 100% white glutinous rice flour (white color). Four pigmented rice varieties were then used to partially substitute the white glutinous rice flour at 10%, 20%, and 30% levels (w/w). These varieties included Sung Yod rice flour (red color, B-SY), Riceberry rice flour (dark purple color, B-RB), Hom Nil rice flour (dark purple to black color, B-HN), and black glutinous rice flour (black color, B-BG). In all formulations, the total flour content was maintained at 240 g, with the pigmented rice flour replacing an equivalent amount of white glutinous rice flour. The remaining ingredients, including arrowroot flour (22.5 g), salt (3 g), sugar (75 g), palm sugar (113 g), coconut milk (150 g), coconut water (75 g), and young grated coconut (300 g), were kept constant across all variations to isolate the effects of the rice flour substitutions.

Fig. (**1**) illustrates the step-by-step process undertaken to prepare the Thai Coconut Pancake. The example described uses only black glutinous rice flour, as the production process remains consistent across all flour types. The six-stage procedure is clearly outlined here: (1) Dry ingredients, including black glutinous rice flour, sugar, and salt, are combined in a stainless steel bowl. (2) The wet ingredients are prepared by dissolving palm sugar in coconut milk. (3) The liquid mixture is then poured into the dry ingredients and thoroughly whisked together. (4) Coconut water is added to the batter and stirred until uniform. (5) Young, freshly grated coconut is incorporated into the mixture, enhancing the texture and flavor. (6) Finally, the batter is poured into a rectangular mold and cooked on a pan over low heat until golden brown on both sides. This description provides a comprehensive overview of the traditional method for making Thai Coconut Pancake, showcasing the careful blending of ingredients to create this beloved Thai dessert while emphasizing that the process is identical regardless of the specific type of Thai pigmented rice flour used.

2.3. Total Phenolic Content and Total Flavonoid Content of the Samples Extracted from the Thai Coconut Pancake

2.3.1. Extraction of Samples

A sample powder of approximately 100 g was extracted with methanol in a ratio of 1:2 (sample 100 g: 200 mL methanol) for 2 days. The extraction solution was centrifuged at 6,000 rpm for 15 min. Then, the supernatant was filtrated with 0.45 µm of syringe filter before the bioactive compounds were determined. All experiments were performed in triplicate biological replicates.

2.3.2. Total Phenolic Content (TPC)

Total phenolic content was determined by the modified method of Archanachai *et al.* [23]. Briefly, 100 µL of sample solution was mixed with 100 µL of methanol (95% v/v) and 200 µL of Folin-Ciocalteu reagent (10% v/v) and shaken for 5 min. Then, 600 µL of 1 M sodium carbonate was added to the mixture solution. The reaction mixture was incubated at room temperature for 30ºC in the dark. The final product was measured at 760 nm by a spectrophotometer. The total phenolic content of samples was calculated by the calibration curve of gallic acid (micrograms of gallic acid equivalent per gram of dry weight).

2.3.3. Total Flavonoid Content (TFC)

Total flavonoid content was determined by the modified method of Archanachai *et al.* [23]. Briefly, 500 µL of the

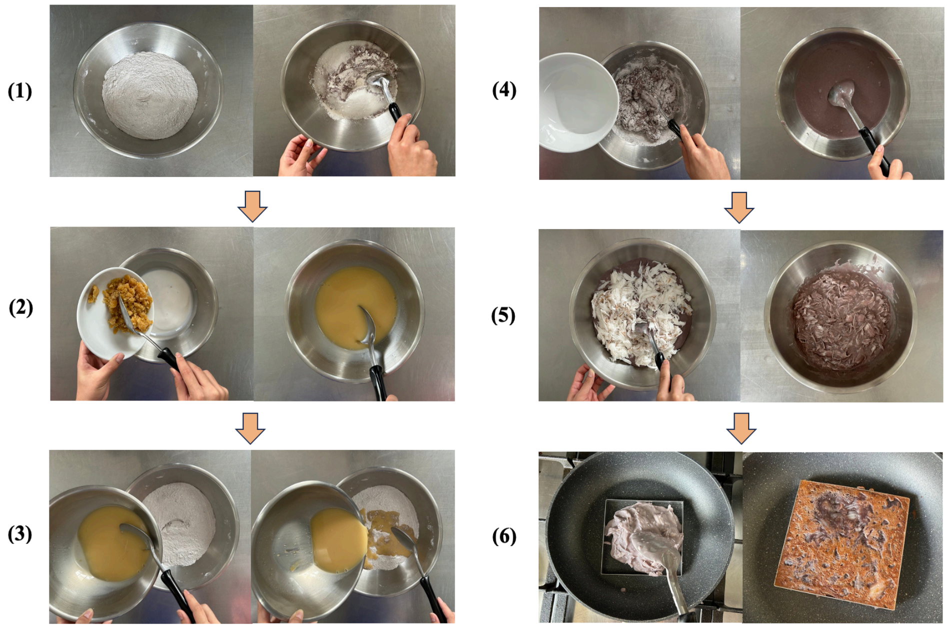

Fig. (1). Flowchart illustrating the sequential process for preparing the Thai Coconut Pancake. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

sample solutions were mixed with 340 µL of deionized water and 30 µL of sodium acetate (1 M) and incubated for 5 min. Then, the reaction solution was mixed with 30 µL of $AlCl_3$ (1 M) and shaken for 5 min. After that, 200 µL of NaOH (1 M) was added and incubated for 15 min at 30°C. Finally, the absorbance of the final product was measured at 415 nm by a spectrophotometer. The total flavonoid content of the sample solution was calculated by the calibration curve of quercetin (micrograms of quercetin equivalent per gram of dry weight).

2.4. Analysis of the Antioxidant Activity of the Samples Extracted from the Extraction Procedure for the Thai Coconut Pancake Samples

2.4.1. Extraction of Samples

The sample extraction was performed using the same method described in Section 2.3.1. The crude extracts were obtained after evaporating the solvent solution in a hot air oven at 50ºC. The crude samples were kept at -20ºC until further experiments. All experiments were performed in triplicate biological replicates.

2.4.2. 2,2-Diphenyl-2-Picrylhydrazyl (DPPH) Antioxidant Assay

The DPPH assay of all samples followed the method of Archanachai *et al.* [23]. For the crude samples, approximately 1 g was dissolved with 1 mL of 10 % (v/v) DMSO to produce a concentration of 1 mg/mL. The 50 µL of sample solution was mixed with 50 µL of 0.1 mM DPPH solution to give the final concentration of 0.5 mg/mL of samples. The reaction mixture was then kept at room temperature for 30 min while being kept in the dark. A UV/Vis spectrophotometer was used to measure the radical inhibition absorbance at 517 nm. [(Ablank- Asample)/Ablank] x 100 was used to calculate the percentage of inhibition. (A_{blank} = absorbance without sample; A_{sample}= absorbance with sample).

2.4.3. ABTS$^{\cdot+}$ Radical Scavenging Assay

The ABTS$^{\cdot+}$ cation radical assay of all samples followed the method of Archanachai *et al.* [23]. The ABTS$^{\cdot+}$ cation solution was prepared with a mixture of 7 mM of ABTS and 2.45 mM of potassium persulfate with a ratio of 1:0.5 v/v. The inhibition potential of samples against the ABTS$^{\cdot+}$ cation radical was determined by mixing 50 µL of samples (0.5 mg/mL final concentration) with 50 µL of ABTS$^{\cdot+}$ solution. The mixed solution then stood at room temperature for 30 min. The inhibition potential was measured at 734 nm. The inhibition percentage was calculated similarly to that of the DPPH assay.

2.5. Sensory Evaluation

Sensory evaluation was conducted to assess Thai Coconut Pancake (Khanom Ba-bin) samples prepared with four different Thai pigmented rice flour varieties. To prevent sensory fatigue and maintain evaluation accuracy, the samples were divided into four testing sessions based on rice flour type: (1) Sung Yod rice flour formulations, (2) Riceberry rice flour formulations, (3) Hom Nil rice flour formulations, and (4) black glutinous rice flour formulations. Each session included the control sample (B-WG) and three substitution levels (10%, 20%, and 30%) of the respective pigmented rice flour. Fifty untrained panelists participated in the evaluation [24]. All panelists were food and nutrition students from the Faculty of Home Economics Technology, Rajamangala University of Technology Thanyaburi, who had completed coursework in experimental design and sensory evaluation. Each panelist received one piece (20 g) of each sample and water was provided for palate cleansing between samples. The samples were evaluated using a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely). The sensory attributes assessed included appearance, color, smell, taste, texture, and overall acceptability [25-28]. A randomized complete block design (RCBD) was employed for sample presentation. Prior to conducting the sensory evaluation, the research protocol was explained to all participants, and written informed consent was obtained. The panelists were informed about the study objectives, procedures, and their right to withdraw from the evaluation at any time [27, 29, 30].

2.6. Statistical Analysis

The data obtained from total phenolic content (TPC), total flavonoid content (TFC), antioxidant activity assays, and sensory evaluation were subjected to one-way analysis of variance (ANOVA). Significant differences among means were determined using Duncan's new multiple range test (DNMRT) at a 95% confidence level ($p < 0.05$). For sensory evaluation data, means within the same rice flour type were compared. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0.

3. RESULTS & DISCUSSION

3.1. Total Phenolic Content, Total Flavonoid Content, and Antioxidant Activity of the Thai Pigmented Rice Flour

The analysis of the chemical composition and antioxidant properties of various Thai pigmented rice flours compared to white glutinous rice flour revealed significant differences ($p < 0.05$) in all studied parameters (Table **2**). These findings highlight the exceptional nutritional value of Thai pigmented rice varieties. The total phenolic content (TPC) of the studied rice flours ranged from 55.07 to 277.41 µg GAE/g dry weight. Black glutinous rice flour exhibited the highest TPC (277.41 ± 0.92 µg GAE/g), followed by Riceberry (245.42 ± 0.77 µg GAE/g), Hom Nil (228.54 ± 0.52 µg GAE/g), and Sung Yod (196.15 ± 0.55 µg GAE/g) rice flours. White glutinous rice flour showed the lowest TPC (55.07 ± 0.49 µg GAE/g). These results are consistent with previous studies reporting higher phenolic content in pigmented rice varieties compared to non-pigmented ones [11, 16, 31, 32]. The variation in TPC among different rice varieties can be attributed to genetic factors, growing conditions, and processing methods [33, 34].

Regarding total flavonoid content (TFC), the values ranged from 37.67 to 252.18 µg QE/g dry weight. Black glutinous rice flour again demonstrated the highest TFC (252.18 ± 0.91 µg QE/g), followed by Hom Nil (205.91 ± 0.80 µg QE/g), Riceberry (175.27 ± 0.79 µg QE/g), and Sung Yod (118.82 ± 0.67 µg QE/g) rice flours. White glutinous rice flour had the lowest TFC (37.67 ± 0.65 µg QE/g). This trend aligns with previous research indicating that purple-black rice grains, such as black glutinous rice, have the highest accumulated total flavonoid content [35, 36]. The high flavonoid content in pigmented rice varieties is primarily due to the presence of anthocyanins, which are responsible for the grain color and contribute significantly to the antioxidant properties [37, 38]. Antioxidant activity analysis using DPPH and ABTS assays showed that Hom Nil rice flour exhibited the highest antioxidant activity in both methods, with 235.95% DPPH inhibition and 307.13% ABTS inhibition at a concentration of 0.5 mg/mL. This was followed by Riceberry and Sung Yod rice flours. Interestingly, black glutinous rice flour showed lower antioxidant activity than these varieties, but it was still significantly higher than white glutinous rice flour. The high antioxidant activities observed in pigmented rice varieties can be attributed to their rich content of phenolic compounds, including phenolic acids, flavonoids, and anthocyanins [11, 12, 39]. These bioactive compounds contribute to the health-promoting properties of pigmented rice, such as reducing the risk of chronic diseases and offering anti-inflammatory effects [14-17, 40]. The variations in TPC, TFC, and antioxidant activities among different pigmented rice varieties can be explained by genetic factors, growing conditions, and processing methods [9, 13, 41]. The consistently higher values for these parameters in pigmented rice flour compared to white glutinous rice flour underscore their potential as functional food ingredients, particularly in enhancing the nutritional and antioxidant properties of food products [22, 42, 43].

3.2. Total Phenolic Content and Total Flavonoid Content of the Thai Coconut Pancake

Table **3** presents the total phenolic content (TPC) and total flavonoid content (TFC) of Thai Coconut Pancake samples prepared with varying ratios of pigmented rice flour substitutions. The results demonstrate significant differences ($p < 0.05$) among all samples for both TPC and TFC. The TPC of the Thai Coconut Pancake samples ranged from 22.48 to 65.39 µg GAE/g dry weight. The control sample (B-WG), made with 100% white glutinous rice flour, exhibited the lowest TPC (22.48 ± 0.60 µg GAE/g). As expected, the incorporation of pigmented rice flours led to a significant increase in TPC across all samples. The highest TPC was observed in B-BG30 (65.39 ± 0.32 µg GAE/g), which contained a 30% black glutinous rice flour substitution. A clear trend in increasing TPC was observed with higher substitution levels of pigmented rice flours. For instance, in the case of black glutinous rice flour substitution, TPC increased from 36.79 ± 0.30 µg GAE/g at a 10% substitution (B-BG10) to 51.09 ± 0.28 µg GAE/g at a 20% substitution (B-BG20), and further to 65.39 ± 0.32 µg GAE/g at a 30% substitution (B-BG30). Similar trends were observed for other pigmented rice flour substitutions. The TFC for Thai Coconut Pancake samples ranged from 2.18 to 63.09 µg QE/g dry weight. The control sample (B-WG) had the lowest TFC (2.18 ± 0.30 µg QE/g), while B-BG30 exhibited the highest TFC (63.09 ± 0.56 µg QE/g). As with TPC, a clear trend in increasing TFC was observed with higher substitution levels of pigmented rice flour. Among the different types of pigmented rice flour substitutions, black glutinous rice flour consistently resulted in the highest TPC and TFC values

Table 2. Total phenolic content, total flavonoid content, and antioxidant activity of the Thai pigmented rice flour.

Samples	TPC	TFC	DPPH Assay	ABTS Assay
White glutinous rice flour	55.07^{e}±0.49	37.67^{e}±0.65	62.43^{e}±0.68	74.76^{e}±0.72
Sung Yod rice flour	196.15^{d}±0.55	118.82^{d}±0.67	182.83^{c}±0.73	255.65^{b}±0.66
Riceberry rice flour	245.42^{b}±0.77	175.27^{c}±0.79	204.21^{b}±0.70	239.08^{c}±0.84
Hom Nil rice flour	228.54^{c}±0.52	205.91^{b}±0.80	235.95^{a}±0.93	307.13^{a}±0.96
Black glutinous rice flour	277.41^{a}±0.92	252.18^{a}±0.91	171.25^{d}±0.86	214.07^{d}±0.63

Note: Values are means ± standard deviations (n = 3). Values with different superscripts within the same column are significantly different ($p < 0.05$). TPC: total phenolic content (micrograms of gallic acid equivalent/g of dry weight), TFC: total flavonoid content (quercetin equivalent/g of dry weight), DPPH assay and ABTS assay: % inhibition at a concentration of 0.5 mg/mL

across all substitution levels, followed by Hom Nil rice flour, Riceberry rice flour, and Sung Yod rice flour. This order aligns with the TPC and TFC values observed in the raw flour samples (Table **2**), suggesting that the bioactive compounds from the pigmented rice flours are effectively retained in the Thai Coconut Pancake product. The significant increase in both TPC and TFC with the incorporation of pigmented rice flour demonstrates the potential of these ingredients to enhance the nutritional value of traditional Thai desserts. This enhancement is particularly noteworthy given that Thai Coconut Pancake is traditionally made with white glutinous rice flour, which has comparatively lower phenolic and flavonoid contents [31, 44]. These findings are consistent with previous studies that have reported increased phenolic and flavonoid contents in food products fortified with pigmented rice flour [19-21, 42]. The higher TPC and TFC values in Thai Coconut Pancake samples with pigmented rice flour substitutions can be attributed to the presence of various bioactive compounds, including anthocyanins, proanthocyanidins, and other phenolic compounds, which are abundant in pigmented rice varieties [11, 12, 37]. The observed increases in TPC and TFC with higher substitution levels suggest that it is possible to significantly enhance the antioxidant properties of Thai Coconut Pancake by incorporating pigmented rice flours, potentially leading to a product with improved health benefits [32, 38].

Fig. (**2**) illustrates the comparison of TPC and TFC in Thai Coconut Pancake with varying substitution ratios of pigmented rice flour. In Fig. (**2A**), which shows the TPC values of Thai Coconut Pancake, increasing the proportion of pigmented rice flour resulted in a significant increase ($p < 0.05$) in TPC values across all substitutions. The control sample (B-WG) exhibited the lowest TPC value, while the 30% black glutinous rice flour substitution (B-BG30) showed the highest. Fig. (**2B**) presents the TFC values of the Thai Coconut Pancake, which followed a similar trend to TPC. An increase in the proportion of pigmented rice flour led to a significant rise in TFC values for all substitutions. Both TPC and TFC values varied in decreasing order among pigmented rice flour substitutions, with black glutinous rice flour showing the highest content, followed by Hom Nil rice flour, Riceberry rice flour, and Sung Yod rice flour, respectively. These findings align with previous studies reporting higher phenolic and flavonoid contents in pigmented rice compared to white rice [11, 16]. The increase in TPC and TFC can be attributed to bioactive compounds such as anthocyanins and proanthocyanidins, which are abundant in pigmented rice varieties [12].

Table 3. Total phenolic content and total flavonoid content of the Thai Coconut Pancake.

Samples	TPC	TFC
B-WG (Control)	22.48^{k}±0.60	2.18^{l}±0.30
B-SY10	29.42^{j}±0.37	9.76^{k}±0.25
B-SY20	36.36^{g}±0.29	17.32^{i}±0.40
B-SY30	43.30^{e}±0.29	24.90^{g}±0.45
B-RB10	33.20^{h}±0.34	16.39^{j}±0.37
B-RB20	43.91^{e}±0.41	30.58^{f}±0.26
B-RB30	54.64^{b}±0.51	44.79^{c}±0.53
B-HN10	31.61^{i}±0.38	17.00^{ij}±0.46
B-HN20	40.73^{f}±0.24	31.87^{e}±0.24
B-HN30	49.85^{d}±0.55	46.72^{b}±0.58
B-BG10	36.79^{g}±0.30	22.49^{h}±0.39
B-BG20	51.09^{c}±0.28	42.79^{d}±0.23
B-BG30	65.39^{a}±0.32	63.09^{a}±0.56

Note: Values are means ± standard deviations (n = 3). Values with different superscripts within the same column are significantly different ($p < 0.05$). B-WG: Thai Coconut Pancake from 100% white glutinous rice flour (control); B-SY10, B-SY20, B-SY30: substituted with 10%, 20%, 30% Sung Yod rice flour, respectively; B-RB10, B-RB20, B-RB30: substituted with 10%, 20%, 30% Riceberry rice flour, respectively; B-HN10, B-HN20, B-HN30: substituted with 10%, 20%, 30% Hom Nil rice flour, respectively; B-BG10, B-BG20, B-BG30: substituted with 10%, 20%, 30% black glutinous rice flour, respectively. TPC: total phenolic content (μg gallic acid equivalent/g dry weight), TFC: total flavonoid content (μg quercetin equivalent/g dry weight).

Fig. (**3**) shows the comparison of TPC and TFC in Thai Coconut Pancakes using different types of pigmented

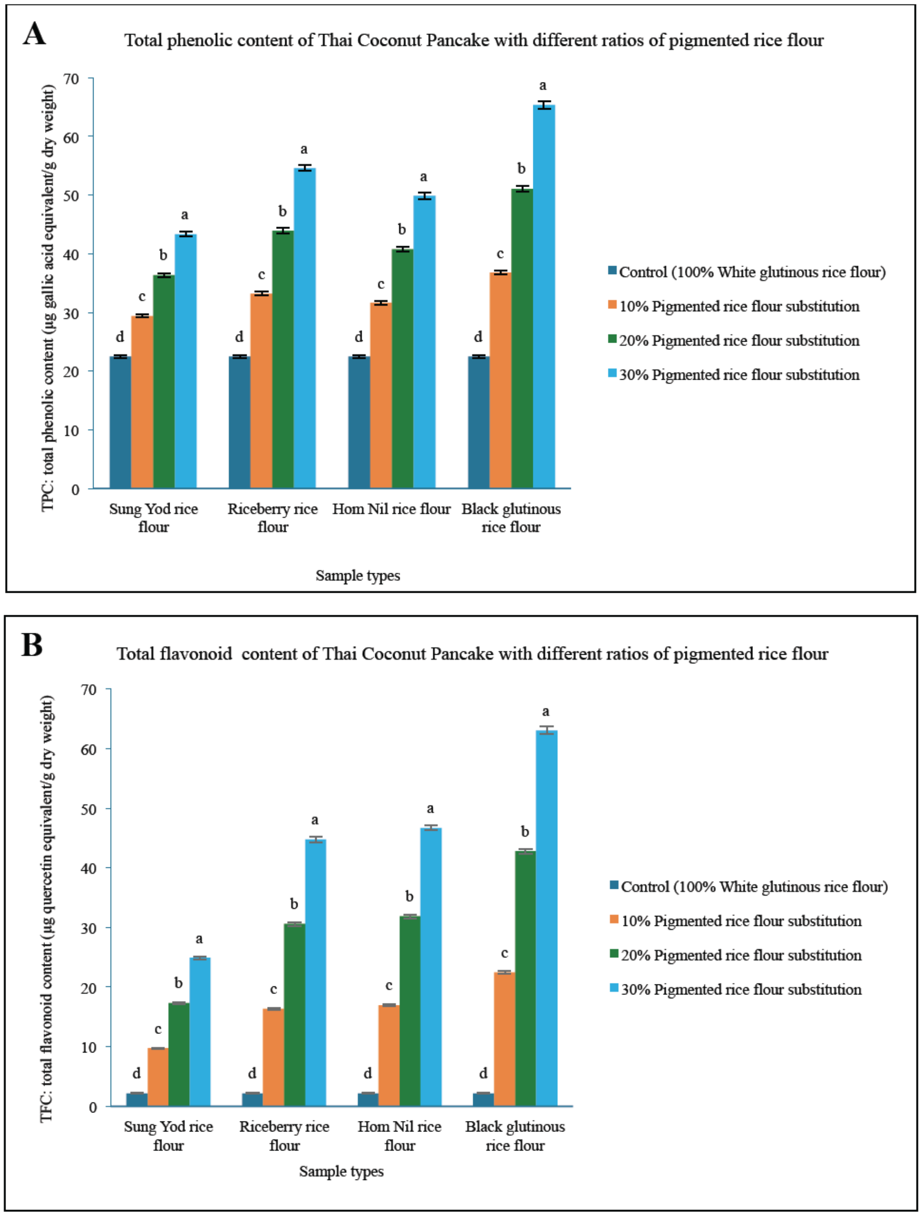

Fig. (2). Comparison of bioactive compounds in Thai Coconut Pancake with different ratios of pigmented rice flour substitution. (**A**) Total phenolic content (TPC) and (**B**) Total flavonoid content (TFC) of Thai Coconut Pancake samples. Values with different superscripts (a, b, c, d) within the same type of pigmented rice flour substitution are significantly different ($p < 0.05$). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

rice flour at equivalent substitution levels (10%, 20%, and 30%). Fig. (**3A**) presents TPC values. Black glutinous rice flour yielded the highest values at all substitution levels (36.79-65.39 µg GAE/g), followed by Riceberry flour (33.20-54.64 µg GAE/g), Hom Nil rice flour (31.61-49.85 µg GAE/g), and Sung Yod rice flour (29.42-43.30 µg GAE/g), respectively. Fig. (**3B**) shows TFC values. Black glutinous rice flour still provided the highest values (22.49-63.09 µg QE/g), but the order of the other pigmented rice flours differed from TPC. Hom Nil rice flour gave the second-highest TFC values (17.00-46.72 µg QE/g), followed by Riceberry flour (16.39-44.79 µg QE/g) and Sung Yod rice flour (9.76-24.90 µg QE/g). Both TPC and TFC values showed a dose-dependent relationship, with higher substitution levels resulting in increased TPC and TFC values for all types of pigmented rice flour. This is consistent with the research of Thitipramote *et al.* [45], which found that pigmented rice contains significantly higher amounts of phenolic compounds and flavonoids compared to white rice. The differences in the order of TPC and TFC among various pigmented rice types may be due to the diversity in types and quantities of phenolic compounds and flavonoids in each rice variety, as reported by Yodmanee *et al.* [12]. The increase in TPC and TFC values in Thai Coconut Pancake substituted with pigmented rice flour may benefit consumers' health, as these compounds possess antioxidant and anti-inflammatory properties [17].

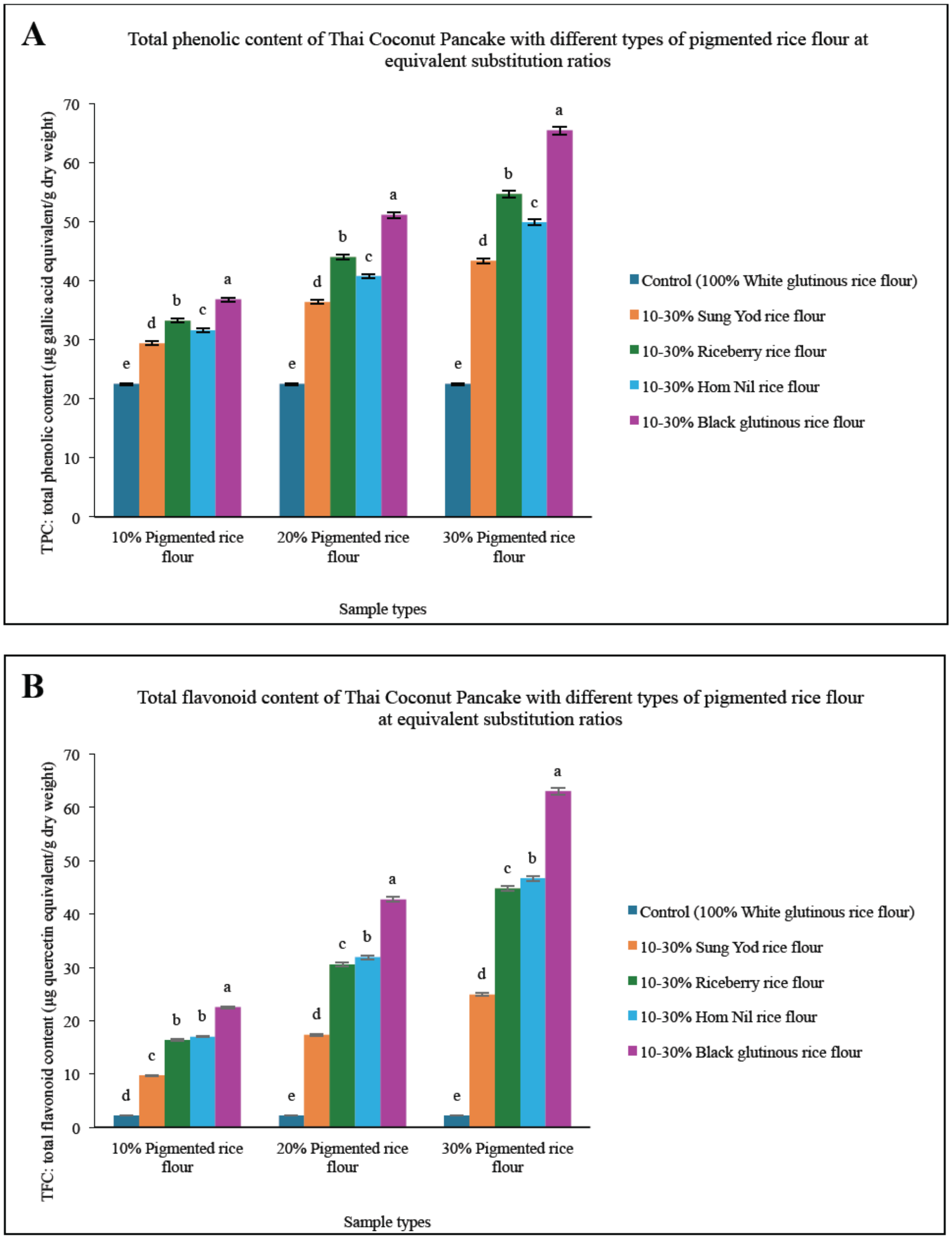

Fig. (3). Comparison of bioactive compounds in Thai Coconut Pancake with different types of pigmented rice flour at equivalent substitution ratios. (**A**) Total phenolic content (TPC) and (**B**) Total flavonoid content (TFC) of Thai Coconut Pancake samples. Values with different superscripts (a, b, c, d, e) within the same substitution ratio are significantly different ($p < 0.05$). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

3.3. Antioxidant Activity of the Thai Coconut Pancake

Table **4** shows the analysis of antioxidant activity in Thai Coconut Pancake with various substitution ratios of pigmented rice flour, using DPPH and ABTS assays. The DPPH assay results indicate that the free radical inhibition values ranged from 23.37% to 31.65% at a concentration of 0.5 mg/mL. The control sample (B-WG) exhibited the lowest value (23.37 ± 0.16%), while the sample with 30% Hom Nil rice flour substitution (B-HN30) had the highest value (31.65 ± 0.43%). Increasing the proportion of pigmented rice flour resulted in a significant increase ($p < 0.05$) in DPPH values across all types of pigmented rice flour. For the ABTS assay, the free radical inhibition values ranged from 28.66% to 60.83% at a concentration of 0.5 mg/mL. The control sample had the lowest value (28.66 ± 0.39%), and the B-HN30 sample had the highest value (60.83 ± 0.45%), similar to the DPPH test results. The analysis revealed that Hom Nil rice flour demonstrated the highest antioxidant activity in both assays. For the DPPH method, Hom Nil rice flour had the highest antioxidant activity followed by Riceberry rice flour, Sung Yod rice flour, and black glutinous rice flour. In the

ABTS method, the order following Hom Nil rice flour was Sung Yod rice flour, Riceberry rice flour, and black glutinous rice flour. These findings are consistent with the study by Ratseewo *et al.* [41], which found that Hom Nil rice had higher antioxidant activity compared to other pigmented rice varieties. The increase in antioxidant activity in Thai Coconut Pancake substituted with pigmented rice flour may be attributed to the phenolic compounds and flavonoids present in pigmented rice [11, 12, 18, 39]. Furthermore, higher substitution levels resulted in significantly increased antioxidant activity, suggesting the potential for developing Thai dessert products with enhanced health properties [8, 9, 43]. This trend is in line with previous studies that have shown a positive correlation between the concentration of pigmented rice flour and antioxidant activity in various food products [33, 35, 40]. The variation in antioxidant activity among different pigmented rice varieties can be attributed to factors such as genetic diversity, growing conditions, and processing methods [34,43]. It is worth noting that while black glutinous rice flour showed the highest TPC and TFC, it did not exhibit the highest antioxidant activity in DPPH and ABTS assays. This discrepancy highlights the complex nature of antioxidant activity and suggests that factors other than total phenolic and flavonoid content may contribute to the overall antioxidant capacity of pigmented rice [38, 44]. This research demonstrates the potential of using pigmented rice flour, especially Hom Nil rice flour, to enhance the antioxidant properties of Thai Coconut Pancake, which could lead to the development of healthier food products with higher nutritional value. The findings contribute to the growing body of evidence supporting the use of pigmented rice in functional food development [32, 40, 42, 46, 47].

Fig. (**4**) shows the comparison of antioxidant activities in Thai Coconut Pancakes with different ratios of pigmented rice flour substitution. Fig. (**4A**) presents the results of the DPPH assay. The data clearly demonstrate that antioxidant activity increases with higher substitution levels of pigmented rice flour across all tested varieties. The control sample (B-WG) made with 100% white glutinous rice flour exhibited the lowest antioxidant activity. As the substitution level for pigmented rice flour increased from 10% to 30%, a consistent increase in radical scavenging activity was observed for all pigmented rice varieties. Fig. (**4B**) shows the results of the ABTS assay, which followed a similar trend to the DPPH assay. Again, higher substitution levels resulted in increased antioxidant activity for all pigmented rice varieties. The sample with 30% Hom Nil rice flour substitution (B-HN30) had the highest antioxidant activity in both assays. These findings are consistent with previous research on various pigmented rice varieties. Ratseewo *et al.* [41] reported that Hom Nil rice had higher antioxidant activity compared to other pigmented rice varieties, which aligns with our experimental results. The increase in anti-oxidant activity may be attributed to bioactive compounds such as phenolic acids, flavonoids, and anthocyanins, which are abundant in pigmented rice [11, 12].

Table 4. Antioxidant activity of the Thai Coconut Pancake.

Samples	DPPH Assay	ABTS Assay
B-WG	23.37^{f}±0.16	28.66^{l}±0.39
B-SY10	24.98^{e}±0.38	36.34^{i}±0.37
B-SY20	26.59^{c}±0.11	44.02^{e}±0.18
B-SY30	28.20^{b}±0.54	51.70^{b}±0.66
B-RB10	25.15d^{e}±0.36	35.14^{j}±0.45
B-RB20	26.92^{c}±0.55	41.61^{f}±0.06
B-RB30	28.69^{b}±0.25	48.08^{d}±0.21
B-HN10	26.13^{cd}±0.28	39.39^{g}±0.36
B-HN20	28.89^{b}±1.60	50.11^{c}±0.26
B-HN30	31.65^{a}±0.43	60.83^{a}±0.45
B-BG10	24.90^{e}±0.39	31.65^{k}±0.26
B-BG20	26.43^{c}±0.52	34.64^{j}±0.36
B-BG30	27.96^{b}±0.56	37.63^{h}±0.44

Note: Values are means ± standard deviations (n = 3). Values with different superscripts within the same column are significantly different ($p < 0.05$). B-WG: Thai Coconut Pancake from 100% white glutinous rice flour (control); B-SY10, B-SY20, B-SY30: substituted with 10%, 20%, 30% Sung Yod rice flour, respectively; B-RB10, B-RB20, B-RB30: substituted with 10%, 20%, 30% Riceberry rice flour, respectively; B-HN10, B-HN20, B-HN30: substituted with 10%, 20%, 30% Hom Nil rice flour, respectively; B-BG10, B-BG20, B-BG30: substituted with 10%, 20%, 30% black glutinous rice flour, respectively. DPPH assay and ABTS assay: % inhibition at a concentration of 0.5 mg/mL.

Fig. (**5**) presents a comparison of DPPH and ABTS assay of antioxidant activities for Thai Coconut Pancake made with different types of pigmented rice flour at equivalent substitution ratios. In Fig. (**5A**), which shows the DPPH assay results, Thai Coconut Pancake substituted with Hom Nil rice flour exhibited significantly higher antioxidant activity at all substitution levels (10%, 20%, and 30%). Meanwhile, Sung Yod rice flour, Riceberry rice flour, and black glutinous rice flour had no significant differences in their antioxidant activities. Fig. (**5B**) displays the results of the ABTS assay, which showed a slightly different pattern from the DPPH assay. Hom Nil rice flour again demonstrated the highest antioxidant activity across all substitution levels, followed by Sung Yod rice flour, Riceberry rice flour, and black glutinous rice flour, respectively, with significant differences between each type. These results indicate that Hom Nil rice has high potential for enhancing antioxidant activity in Thai Coconut Pancake. This is consistent with the research of Thitipramote *et al.* [45], which found that Hom Nil rice had higher antioxidant activity compared to other pigmented rice varieties. Furthermore, Sansenya and Nanok [46] reported that extracts from Hom Nil rice showed highly effective antioxidant activity in both DPPH and ABTS assay.

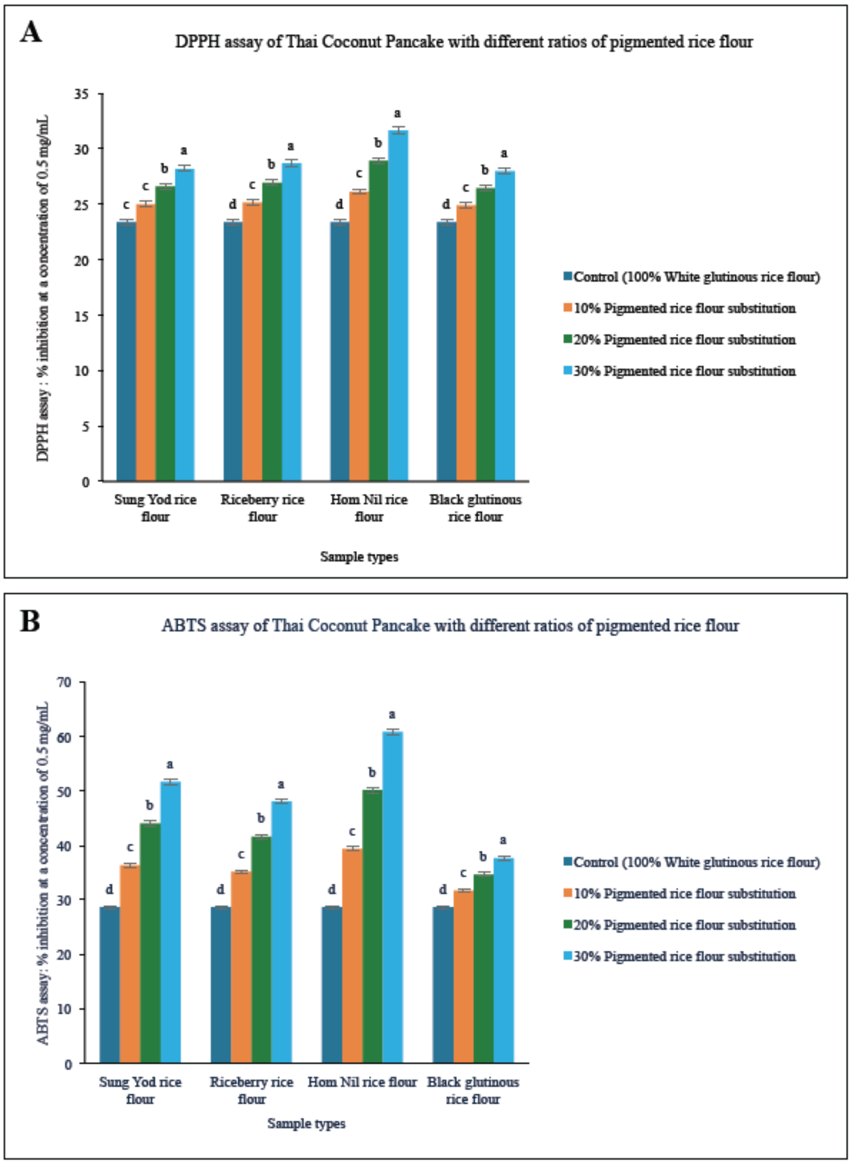

Fig. (4). Comparison of antioxidant activities in Thai Coconut Pancake with different ratios of pigmented rice flour substitution. (**A**) DPPH assay and (**B**) ABTS assay of Thai Coconut Pancake samples. Values with different superscripts (a, b, c, d) within the same type of pigmented rice flour substitution are significantly different ($p < 0.05$). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

The differences in antioxidant activity among various pigmented rice types and the disparities between DPPH and ABTS assay results may be due to variations in the types and quantities of phenolic compounds, especially anthocyanins, which are the pigments in each type of colored rice. Additionally, these differences could be attributed to the varying sensitivities of each testing method to different antioxidants [9, 11, 47].

The antioxidant mechanisms of pigmented rice flour can be attributed to several pathways. The phenolic compounds exist in two forms: free and bound forms, with the bound phenolic acids being covalently linked to cell wall components such as cellulose, hemicellulose, and lignin [16]. This structural arrangement contributes to their sustained antioxidant activity throughout processing and storage. The antioxidant properties of phenolic compounds, particularly anthocyanins (cyanidin-3-glucoside and peonidin-3-glucoside), are due to their hydroxyl groups bonded to aromatic rings, which can donate electrons to stabilize reactive oxygen species (ROS) [18, 48, 49]. This structure-function relationship explains the strong antioxidant activity observed in our DPPH and ABTS assays. Additionally, flavonoids and phenolic acids like ferulic acid, vanillic acid, and p-coumaric acid present in pigmented rice contribute to its antioxidant properties [50,51]. Anthocyanins also exhibit nitric oxide (NO•) inhibitory effects through dual mechanisms: direct NO• scavenging and suppression of inducible nitric oxide synthase (iNOS) expression at both protein and mRNA levels in activated macrophages [49]. The synergistic effects between different bioactive compounds, including phenolics, flavonoids, and tocopherols, in both free and bound forms, may

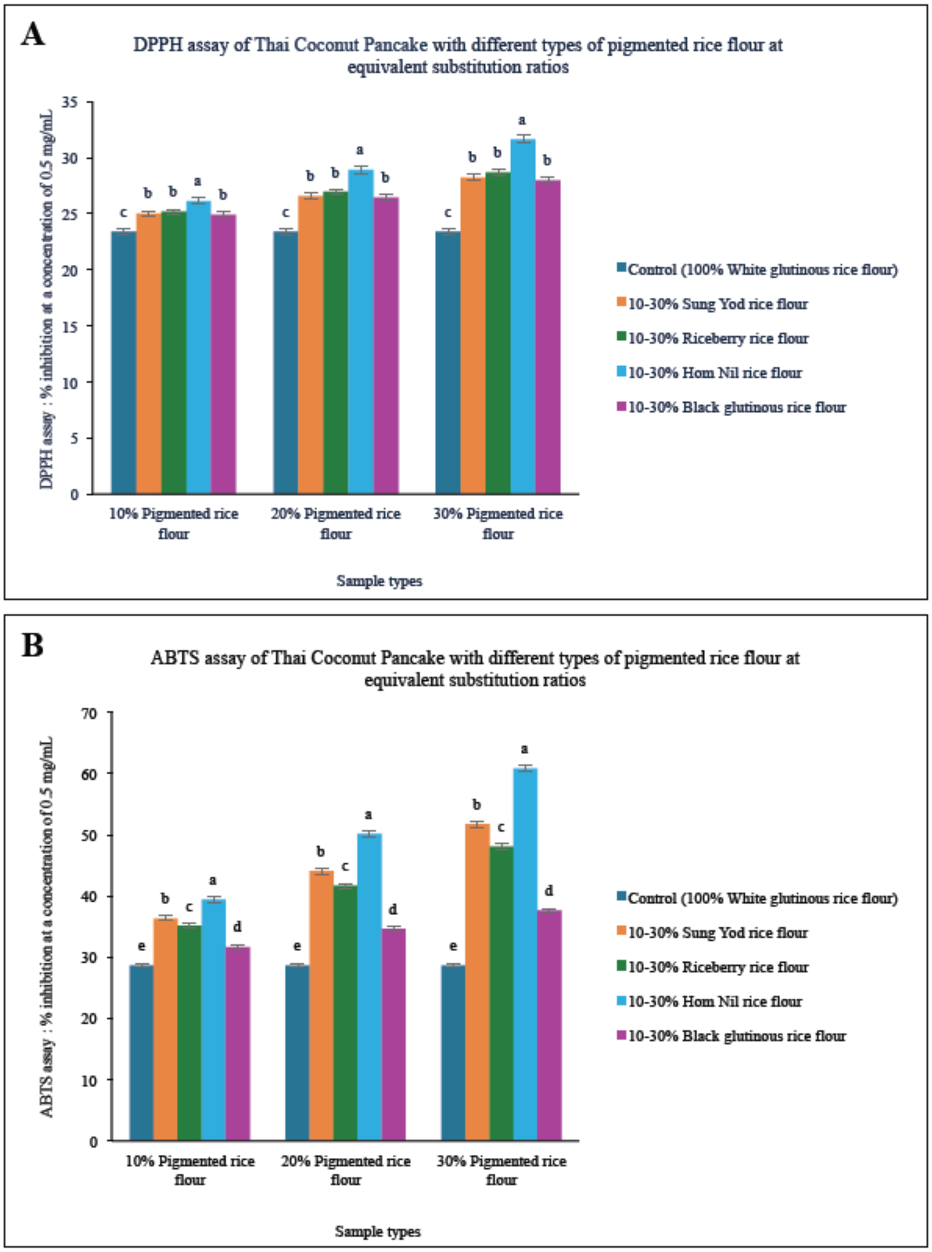

Fig. (5). Comparison of antioxidant activities in Thai Coconut Pancake with different types of pigmented rice flour at equivalent substitution ratios. (**A**) DPPH assay and (**B**) ABTS assay of Thai Coconut Pancake samples. Values with different superscripts (a, b, c, d, e) within the same substitution ratio are significantly different ($p < 0.05$). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

enhance their overall protective capacity [11], leading to the enhanced antioxidant activities observed in our study. The higher antioxidant activity observed in Hom Nil rice flour substitution suggests a potentially more effective free radical scavenging capacity compared to other varieties, which aligns with previous studies on Thai pigmented rice varieties [41] and can be attributed to its optimal composition of these bioactive compounds.

The enhanced antioxidant properties of Thai Coconut Pancake substituted with pigmented rice flour may contribute to various health benefits. Research has established positive correlations between the consumption of pigmented rice and reduced incidence of cancer, cardiovascular disease, and heart disease in Asian populations [52]. Thai pigmented rice varieties have demonstrated effectiveness in reducing the risks of chronic diseases such as cardiovascular disease, obesity, type 2 diabetes, and certain cancers [34, 53, 54]. The high antioxidant activity of pigmented rice extracts has a positive correlation with total phenolic and flavonoid content [55], suggesting potential health-promoting properties. Additionally, pigmented rice contains significant amounts of minerals, vitamins, and dietary fiber that contribute to its overall health benefits [56]. Several factors influencing inflammatory activity include reactive oxygen species, production of nitric oxide and cytokine, dominant expression of matrix

Table 5. Sensory evaluation of Thai Coconut Pancake prepared by substituting white glutinous rice flour with different Thai pigmented rice flours.

Characteristics	B-WG (Control)	B-SY10	B-SY20	B-SY30
Appearance (ns)	7.42±1.21	7.30±1.16	7.76±0.96	7.70±1.01
Color	7.24^{b}±1.25	7.38^{ab}±1.19	7.82^{a}±0.87	7.58^{ab}±1.01
Smell (ns)	7.56±1.07	7.24±1.17	7.68±1.13	7.40±1.16
Taste (ns)	7.76±0.91	7.38±1.24	7.84±0.95	7.54±1.26
Texture	8.08^{a}±0.90	7.30^{b}±1.26	7.78^{ab}±1.37	7.46^{b}±1.35
Overall acceptability	7.80^{ab}±0.90	7.50^{b}±1.01	8.00^{a}±0.96	7.82^{ab}±1.10
	B-WG (Control)	**B-RB10**	**B-RB20**	**B-RB30**
Appearance	7.12^{b}±1.53	7.70^{a}±1.12	7.72^{a}±1.16	7.12^{b}±1.30
Color	6.78^{b}±1.71	7.68^{a}±1.07	7.70^{a}±1.35	6.92^{b}±1.46
Smell	7.48^{a}±1.46	7.28^{a}±1.14	7.66^{a}±6.78	7.30^{b}±1.40
Taste (ns)	7.58±1.50	7.48±1.31	7.76±1.22	7.48±1.47
Texture (ns)	7.62±1.30	7.50±1.35	7.54±1.43	7.18±1.50
Overall acceptability	7.62^{a}±1.19	7.68^{a}±0.97	7.78^{a}±1.21	7.04^{b}±1.30
	B-WG (Control)	**B-HN10**	**B-HN20**	**B-HN30**
Appearance	7.32^{b}±1.25	7.76^{ab}±1.20	7.94^{a}±0.89	7.60^{ab}±1.29
Color (ns)	7.36±1.32	7.68±1.25	7.86±0.92	7.40±1.34
Smell (ns)	7.34±1.23	7.46±1.09	7.72±0.99	7.26±1.15
Taste	7.28^{b}±1.32	7.56^{b}±1.38	8.18^{a}±0.91	7.38^{b}±1.32
Texture (ns)	7.32±1.43	7.74±1.24	7.72±1.29	7.18±1.46
Overall acceptability	7.44^{b}±1.31	7.80^{ab}±1.12	8.06^{a}±0.93	7.54^{b}±1.16
	B-WG (Control)	**B-BG10**	**B-BG20**	**B-BG30**
Appearance	7.26^{b}±1.24	7.46^{ab}±1.11	7.90^{a}±0.93	7.42^{b}±1.16
Color	7.02^{b}±1.22	7.40^{ab}±1.05	7.78^{a}±0.91	7.26^{b}±1.19
Smell (ns)	7.30±1.09	7.14±1.17	7.36±1.04	6.98±1.22
Taste	7.54^{a}±1.11	7.44^{a}±1.26	7.72^{a}±1.17	6.86^{b}±1.42
Texture	7.70^{a}±1.07	7.30^{ab}±1.12	7.78^{a}±1.05	7.14^{b}±1.42
Overall acceptability	7.70^{a}±1.01	7.68^{a}±1.09	7.92^{a}±0.98	7.24^{b}±1.23

Note: Values are means ± standard deviations (n = 50). Values with different superscripts within the same row are significantly different ($p < 0.05$). ns = not significant ($p \geq 0.05$). B-WG: Thai Coconut Pancake from 100% white glutinous rice flour (control); B-SY10, B-SY20, B-SY30: substituted with 10%, 20%, 30% Sung Yod rice flour, respectively; B-RB10, B-RB20, B-RB30: substituted with 10%, 20%, 30% Riceberry rice flour, respectively; B-HN10, B-HN20, B-HN30: substituted with 10%, 20%, 30% Hom Nil rice flour, respectively; B-BG10, B-BG20, B-BG30: substituted with 10%, 20%, 30% black glutinous rice flour, respectively.

metalloproteinases, and secretion of inflammatory enzymes like NO synthase and cyclooxygenase-2 [11]. According to Das *et al.* [48], regular consumption of pigmented rice and its products has been shown to have the potential to reduce oxidative stress, inflammation, and various disorders through multiple mechanisms. The anthocyanins present in pigmented rice particularly demonstrate anti-inflammatory effects by inhibiting proteins involved in inflammatory processes, such as matrix metalloproteinase expression [57]. Pigmented rice varieties have been reported to be a storehouse of bioactive compounds like anthocyanin, proanthocyanidins, gamma-oryzanol, and ferulic acid, which possibly catalyze the secretion of anti-inflammatory enzyme superoxide dismutase [58, 59]. Moreover, the fiber content and low glycemic index of pigmented rice make it beneficial for digestive health and blood sugar control.

3.4. Sensory Characteristics of Thai Coconut Pancake

The sensory evaluation results for the Thai Coconut Pancake samples with different Thai-pigmented rice flour substitutions shown in Table **5**. For Sung Yod rice flour substitution, most sensory attributes (appearance, smell, and taste) showed no significant differences ($p \geq 0.05$) among all samples. However, texture scores were significantly lower ($p < 0.05$) in substituted samples compared to the control, except for B-SY20. Overall acceptability scores were highest for B-SY20 (8.00 ± 0.96), though not significantly different from the control and B-SY30. For Riceberry rice flour substitution, samples with 10% and 20% substitution (B-RB10 and B-RB20) showed significantly higher scores ($p < 0.05$) in appearance and color compared to the control and 30% substitution (B-RB30). There were no significant differences in taste and texture among the samples. However, overall acceptability significantly decreased at the 30% substitution level, for Hom Nil rice flour substituted samples, appearance and taste scores were highest for B-HN20 (7.94 ± 0.89 and 8.18 ± 0.91, respectively). There were no significant differences among samples for color, smell, and texture. Overall acceptability was significantly higher ($p < 0.05$) for B-HN20 (8.06 ± 0.93) compared to the other samples. For black glutinous rice flour substitution, B-BG20 received the highest scores in most attributes, including appearance (7.90 ± 0.93) and color (7.78 ± 0.91). However, at the 30% substitution level (B-BG30), significant decreases were observed in taste, texture, and overall acceptability scores. These findings align with previous studies. Itthivadhanapong and Sangnark [21] reported that Thai pigmented rice flour, such as black glutinous rice flour, could partially or fully substitute wheat flour in cake products without affecting consumer acceptance. Similarly, Mau *et al.* [60] demonstrated that chiffon cake made with black rice flour could substitute wheat flour by up to 60% while maintaining consumer acceptance, highlighting the successful application of Thai pigmented rice in bakery products. Furthermore, Sirichokworrakit *et al.* [61] investigated the feasibility of using pigmented rice in food products and found that Riceberry flour could substitute wheat flour in noodle products by up to 30%. This trend was also observed in a study by Thongkaew and Singthong [62], who developed rice noodles using Riceberry flour as a substitute for white rice flour and found that 20% substitution yielded high-quality products with good consumer acceptance. Overall, these findings demonstrate promising opportunities for incorporating Thai-pigmented rice flour into traditional Thai desserts, offering a pathway to enhance their nutritional properties while preserving consumer acceptance.

CONCLUSION

This research successfully demonstrated the potential of using Thai pigmented rice flour to enhance the nutritional value and antioxidant properties of Thai Coconut Pancake (Khanom Ba-bin), a traditional Thai dessert. The substitution of white glutinous rice flour with pigmented rice flour (Sung Yod, Riceberry, Hom Nil, and black glutinous rice) resulted in significant increases in total phenolic content, total flavonoid content, and antioxidant activities. These antioxidant properties are attributed to several mechanisms, including free radical scavenging through electron donation by phenolic compounds, particularly anthocyanins, and the synergistic effects between free and bound forms of bioactive compounds. Black glutinous rice flour showed the highest potential for increasing phenolic and flavonoid contents, while Hom Nil rice flour was the most effective in enhancing antioxidant activities. Sensory evaluation indicated that a 20% substitution level provided optimal sensory characteristics across all pigmented rice flour types, demonstrating the potential for developing nutritionally enhanced Thai desserts while maintaining consumer acceptance. This dose-response relationship aids in formula optimization. The incorporation of Thai pigmented rice flour preserves cultural heritage while creating functional foods with health benefits through antioxidant mechanisms that may prevent chronic diseases. Future research should focus on clinical studies into the bioavailability and stability of these compounds during processing and storage. This study advances knowledge in pigmented rice utilization for developing healthier traditional desserts.

LIMITATIONS

This study has several limitations to acknowledge. The research examined only four Thai pigmented rice flour varieties, potentially overlooking other valuable varieties. The analysis focused on total phenolic content, flavonoid content, and antioxidant activities without characterizing specific bioactive compounds. Additionally, the study did not assess the stability of bioactive compounds during storage or their bioavailability in vivo. Future research should address these limitations to provide more comprehensive insights into the health benefits of Thai pigmented rice flour in traditional desserts.

AUTHORS' CONTRIBUTIONS

C.P. performed the experiments, analyzed the data, wrote the manuscript draft, and revised the manuscript. R.C. and S.S. performed the experiments and data collection. S.B. contributed to the research methodology and data analysis. P.T. and K.S. conducted experiments, performed data analysis, and assisted with sample preparation and laboratory analyses. K.C. designed the research, supervised the experiments, analyzed the data, wrote the manuscript draft, and revised the final manuscript. All authors reviewed and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

TPC	=	Total Phenolic Content
TFC	=	Total Flavonoid Content
B-WG	=	Thai Coconut Pancake (Khanom Ba-bin) from 100% white glutinous rice flour (control)
B-SY10	=	Thai Coconut Pancake (Khanom Ba-bin) substituted with 10% Sung Yod rice flour
B-SY20	=	Thai Coconut Pancake (Khanom Ba-bin) substituted with 20% Sung Yod rice flour
B-SY30	=	Thai Coconut Pancake (Khanom Ba-bin) substituted with 30% Sung Yod rice flour
B-RB10	=	Thai Coconut Pancake (Khanom Ba-bin) substituted with 10% Riceberry rice flour
B-RB20	=	Thai Coconut Pancake (Khanom Ba-bin) substituted with 20% Riceberry rice flour

B-RB30 = Thai Coconut Pancake (Khanom Ba-bin) substituted with 30% Riceberry rice flour

B-HN10 = Thai Coconut Pancake (Khanom Ba-bin) substituted with 10% Hom Nil rice flour

B-HN20 = Thai Coconut Pancake (Khanom Ba-bin) substituted with 20% Hom Nil rice flour

B-HN30 = Thai Coconut Pancake (Khanom Ba-bin) substituted with 30% Hom Nil rice flour

B-BG10 = Thai Coconut Pancake (Khanom Ba-bin) substituted with 10% black glutinous rice flour

B-BG20 = Thai Coconut Pancake (Khanom Ba-bin) substituted with 20% black glutinous rice flour

B-BG30 = Thai Coconut Pancake (Khanom Ba-bin) substituted with 30% black glutinous rice flour

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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