

From coconut to papaya: A study of sensory and nutritional qualities in Thai dessert



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Abstract Thai desserts are renowned for their unique characteristics, with coconut being a crucial ingredient. However, the limited availability and high cost of mature coconut pose challenges for dessert production. This study aimed to investigate green papaya substitution in caramelized grated coconut (Na Kra Cheek) and evaluate its properties and application. Different substitution levels (0%, 25%, 50%, 75%, and 100% w/w) were analyzed for sensory qualities, nutritional properties, and consumer acceptance through expert panels (n=15) and consumer testing (n=50). The results showed that 50% substitution maintained sensory acceptance comparable to the control ($p \geq 0.05$) in appearance, taste, texture, and overall acceptance while reducing protein content from 2.15% to 1.23%, fat content from 13.70% to 6.83%, and total carbohydrate content from 64.80% to 58.31%. The application in sticky rice dessert demonstrated no significant differences ($p \geq 0.05$) in consumer acceptance between control and 50% substitution formulas in all characteristics including appearance, color, smell, taste, texture, and overall acceptability, with overall acceptability scores of 7.50 ± 0.78 and 7.28 ± 0.85 , respectively. Production costs decreased by 36.24% with 50% substitution. These findings suggest that green papaya can effectively substitute for mature coconut up to 50% in Thai desserts, offering cost-effective and healthier alternatives while maintaining traditional qualities. This innovation provides practical solutions for addressing both availability and cost challenges in Thai dessert production while potentially offering more nutritious options to consumers. The similarity in physical properties and the year-round availability of green papaya make this a viable approach for preserving Thai culinary traditions while addressing contemporary economic and nutritional considerations.

Keywords: Thai food, recipe modification, sensory, nutritional properties, alternative ingredients

1. Introduction

Thai desserts represent one of Thailand's most distinctive cultural identities and have been well known and preserved since ancient times. These desserts reflect the meticulous attention given to detail in their preparation, from carefully selecting ingredients to the intricate cooking processes. They showcase refined tastes, colors, aromas, aesthetics, and unique serving methods that epitomize Thai identity and inherent values, reflecting a way of life that has been passed through generations as part of Thailand's cultural heritage. Most Thai desserts are made from natural ingredients that are locally sourced and seasonally available. The main ingredients typically consist of flour, sugar, and coconut, as these are commonly found in local ingredients (Boonchai, 2020; Chomshome et al., 2024; Layim, 2022; Mongkolvanit and Chartwong, 2014; Songnearm et al., 2025).

As previously mentioned, the main ingredients in Thai desserts—flour, sugar, and coconut—are crucial to their preparation. Coconut, in particular, is indispensable in Thai dessert making. There are three types of coconut commonly used in Thai desserts. First, young coconut is used as a topping or filling material to enhance flavor and provide a soft texture. Second, mature coconut (not too young or too old) is preferred for making fillings, and caramelized grated coconut (Na Kra Cheek) is cooked with palm sugar. Third, fully mature coconut is used to extract coconut milk, an essential ingredient in almost all Thai desserts. Thus, coconut has played and continues to play a vital role in Thai dessert production both historically and in contemporary times (Chumkaew, 2020; Manantapong, 2017).

Currently, mature coconut is highly popular in Thai dessert preparation and is widely consumed. However, several challenges are associated with mature coconut. The primary issue is its limited availability. Determining the optimal harvesting time for mature coconut is particularly challenging; the coconuts may be either too young or too old. This limitation is compounded by their high cost. During seasons when coconuts are scarce on the market, the price of mature coconuts



increases significantly. These factors can create obstacles in Thai dessert production, potentially leading to higher production costs due to increased raw material expenses (Chumkaew, 2020).

Papaya (*Carica papaya* L.) is a tropical fruit that is widely cultivated and consumed in many countries (De Oliveira et al., 2011; Wijaya, 2013; Zhou et al., 2021), with Thailand being one of the major producers. Green papaya has established its importance in Thai cuisine, most notably as the main ingredient in the popular dish 'Som Tam' (papaya salad), with major cultivation areas concentrated in the northeastern region of the country. The preferred varieties for green consumption include 'Khaek Dam', which is characterized by large fruits and crispy flesh, and 'Khaek Nuan'. Green papaya can be harvested quickly within 4–5 months after planting, with harvesting possible approximately twice per month. The market price of green papaya fluctuates according to supply and demand conditions (Thongyaem and Ketthongkam, 2021).

Therefore, researchers are interested in studying the substitution of mature coconut with green papaya in a traditional Thai dessert, specifically, caramelized graded coconut (Na Kra Cheek), as green papaya possesses suitable physical properties, including a crispy texture, white color similar to that of mature coconut, and good grating characteristics. Previous studies have shown that green papaya has potential for processing with heat and sugar (Thongyaem and Ketthongkam, 2021), which is consistent with research that has shown that green papaya is suitable for candying and dehydration processes while maintaining its physical quality and nutritional value (El-Aouar et al., 2006; Fernandes et al., 2006; Jain et al., 2011; Prohmpratae, 2008; Thalerngnawachart, 2011).

However, a review of previous research revealed that no studies have directly investigated the use of green papaya as a substitute for mature coconut in Thai desserts, particularly in caramelized graded coconut products. This study presents an interesting opportunity, as it has the potential to reduce production costs through the use of less expensive raw materials. Additionally, according to the Food Composition Table of Thai Foods (Bureau of Nutrition, 2018), green papaya contains substantially lower fat and carbohydrate contents than mature coconut does, which may result in Thai dessert products with nutritional value that are more suitable for contemporary consumers. Therefore, this study aims to investigate the impact of the substitution of green papaya with mature coconut on the sensory evaluation of caramelized coconut, compare the nutritional properties, and examine the feasibility of applying the developed product in traditional Thai desserts.

2. Literature Review

2.1. Knowledge of Thai Desserts

Thai desserts represent one of Thailand's most distinctive cultural identities and have been well known and preserved since ancient times. These traditional desserts focus meticulous attention on detail in their preparation, from ingredient selection to processing methods. They exhibit refined tastes, colors, aromas, aesthetic appeal, and unique serving methods that epitomize Thai identity and inherent cultural values, reflecting a way of life that has been passed down through generations. Thai desserts can be categorized into different types on the basis of their preparation methods, cooking techniques, and serving characteristics. The categories include the following: 1) Fried desserts; 2) Steamed desserts; 3) Boiled desserts; 4) Baked desserts; 5) Grilled and roasted desserts; 6) Preserved desserts; 7) Boiled in syrup desserts; 8) Jellied desserts; 9) Coconut cream-based desserts; 10) Sweetened shaved ice desserts; 11) Pudding-type desserts; 12) Stuffed desserts; and 13) Crushed ice desserts (Joysriket, 2016; Jungpattana and Kruasom, 2022).

2.2. Trends in Thai Dessert Product Development

Currently, Thai dessert product development shows diverse trends in response to changing consumer demands. Boonchai (2020) reported that modern Thai dessert development focuses on preserving traditional identity while adapting to contemporary lifestyles, considering inherited traditions and beliefs. With respect to health-oriented product development, Layim (2022) reported that Thai dessert development trends emphasize improvements in nutritional value, such as reducing sugar and fat contents, increasing fiber content, reducing costs, and using healthy ingredients. Additionally, Chomshome et al. (2024) reported that communicating a Thai dessert identity and developing modern packaging influences consumer purchasing decisions.

In terms of consumer acceptance, Mongkolvanit and Chartwong (2014) studied Thai dessert images among Thai youth and reported that development should consider the taste preferences of the new generation, convenience in consumption, and modern presentation while maintaining Thai identity. Furthermore, there are trends in developing Thai desserts for commercial purposes, such as extending shelf life, developing packaging, and adding value through the use of unique local ingredients (Mongkolvanit and Chartwong, 2014), aligning with market demands and supporting the community economy.

2.3. Sensory Perception and Consumer Expectations in Food Evaluation

The evaluation of food products is deeply rooted in both past experiences and innate assessment patterns. According to Jantathai et al. (2014), sensory expectations are shaped primarily by previous encounters with similar products and personal familiarity. The expectation formation process begins with the subjective interpretation of food product stimuli, where various

quality cues provide initial insights into the anticipated consumption experience. Sensory evaluation is a scientific discipline that applies principles of experimental design and statistical analysis to the assessment of consumer perceptions (Lawless and Heymann, 2010). This methodology encompasses various testing procedures, including discrimination testing, descriptive analysis, and consumer acceptance testing. Each method serves different objectives in product development and quality control, providing systematic approaches to understanding human sensory responses to food products. The sensory evaluation process is inherently multimodal, engaging multiple sensory channels. It commences with distal perception through visual and acoustic cues before actual tasting occurs. During consumption, the process continues proximally, activating chemical and physical sensory systems in both the oral and nasal regions. Stone et al. (2020) emphasized that proper sensory evaluation requires careful control of testing conditions, including sample preparation, presentation order, and environmental factors, to minimize bias and ensure reliable results.

Descriptive analysis, as highlighted by Kemp et al. (2018), represents one of the most sophisticated tools in sensory evaluation, providing detailed sensory profiles of products through trained panels. This method enables the quantification of sensory attributes and their intensities, facilitating objective product comparisons and the optimization of formulations on the basis of specific sensory characteristics. Consumer behavior is significantly influenced by these quality cues. Research has shown that consumers are more likely to consume products when quality cues suggest a positive taste experience, while they tend to avoid products that are expected to taste unsatisfactorily (Brunso and Grunert, 2007; Jantathai et al., 2014).

3. Materials and methods

3.1. Source of the raw materials

The raw materials for the caramelized coconut included mature coconut and green papaya, which were purchased from markets in Pathum Thani Province. Palm sugar from the Mitr Phol brand, produced by MITR PHOL SUGAR CORP., LTD., and salt from the Tipp brand, produced by THAI REFINED SALT CO., LTD.

3.2. Formulation and production process of caramelized grated coconut

The caramelized coconut formula, detailed in Table 1, specifies ingredient quantities in grams. This systematic study investigated the substitution of mature coconut with green papaya at various weight-to-weight (w/w) ratios with standardized sample designations: control (100% mature coconut); GP25 (25% mature coconut substituted with green papaya w/w); GP50 (50% mature coconut substituted with green papaya w/w); GP75 (75% mature coconut substituted with green papaya w/w); and GP100 (100% mature coconut substituted with green papaya w/w).

The standardized preparation process involved grating mature coconut and green papaya using a cheese grater to achieve uniform strands. The ingredients were systematically mixed, incorporating palm sugar and salt, and then subjected to controlled thermal processing. The mixture was continuously stirred at low heat for 20–30 min until the optimal moisture content was achieved. The resulting caramelized coconut formulation is shown in Figure 1. This methodology was adapted from the preparation technique described by Chumkaew (2020). Sensory evaluation samples were immediately tested on the production day to ensure freshness and prevent overnight storage. For nutritional analysis, samples were carefully sealed in laminate bags via heat sealing techniques and stored at a consistent temperature of -18°C to maintain sample integrity prior to comprehensive analysis. The control formula was adapted from Chumkaew (2020).

3.3. Sensory evaluation

The sensory evaluation was conducted by a panel of 15 expert Thai cuisine professionals, who assessed five caramelized grated coconut samples (15 grams per sample): control (100% mature coconut), GP25 (25% green papaya substitution), GP50 (50% green papaya substitution), GP75 (75% green papaya substitution), and GP100 (100% green papaya substitution). Using a 9-point hedonic scale, where 1 represents "extremely dislike" and 9 represents "extremely like", the panelists evaluated six key sensory attributes: appearance, color, smell, taste, texture, and overall acceptability (Oric et al., 2023; Punfujinda et al., 2021; Punfujinda et al., 2022; Punfujinda et al., 2024). Scores were evaluated using the following interpretation criteria: scores between 2 and 4 indicated fair acceptance, scores between 5 and 6 indicated good acceptance, and scores between 7 and 8 indicated very good acceptance (Kohli et al., 2023; Punfujinda et al., 2025a). To minimize sensory fatigue and ensure accurate assessments, water was provided between sample tastings. Each 15-gram sample was freshly prepared on the day of evaluation and tested in triplicate (three replications) to ensure the reliability and reproducibility of the results. The experimental design followed a randomized complete block design (RCBD) (Namkham et al., 2024). The methodology adhered to rigorous sensory analysis protocols, with a focus on providing a comprehensive and unbiased evaluation of innovative caramelized grated coconut formulations.

3.4. Nutritional properties

Nutritional value analysis was performed via the proximate analysis method for all five caramelized-grated coconut samples: control, GP25, GP50, GP75, and GP100. The parameters analyzed included moisture, ash, protein, fat, total

carbohydrate, and dietary fiber, which were determined via the AOAC method (AOAC, 2019). Statistical analysis was subsequently conducted to compare differences between samples.

Table 1 Caramelized coconut formulas with green papaya substitution at different mature coconut ratios.

Ingredients (g)	Control	GP25	GP50	GP75	GP100
Mature coconut	600	450	300	150	-
Green papaya	-	150	300	450	600
Palm sugar	400	400	400	400	400
Salt	2	2	2	2	2

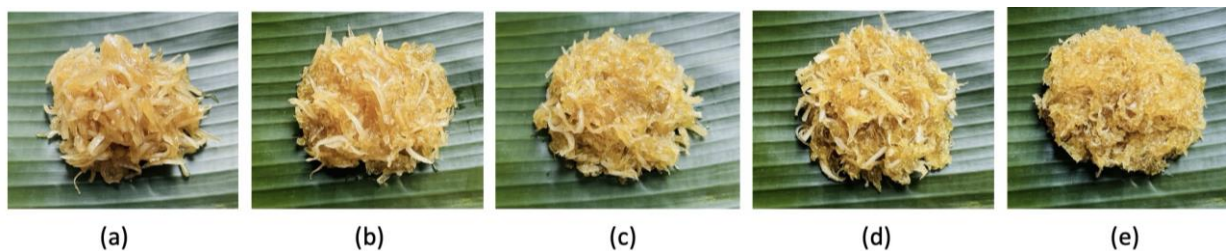


Figure 1 Caramelized coconut with green papaya substitution at different mature coconut ratios: (a): control (100% mature coconut), (b): 25% green papaya substitution (GP25), (c): 50% green papaya substitution (GP50), (d): 75% green papaya substitution (GP75), (e): 100% green papaya substitution (GP100).

3.5. Application of caramelized coconut in a Thai dessert

This study explored the application of the most sensory-preferred caramelized coconut formula, which substitutes mature coconut with green papaya, in traditional Thai sticky rice desserts. The evaluation involved 50 untrained panelists who assessed samples (15 grams per serving) via a 9-point hedonic scale (1 = "extremely dislike", 9 = "extremely like") for appearance, color, smell, taste, texture, and overall acceptability (Oric et al., 2023; Punfujinda et al., 2021; Punfujinda et al., 2022; Punfujinda et al., 2024). Scores were evaluated using the following interpretation criteria: scores between 2 and 4 indicated fair acceptance, scores between 5 and 6 indicated good acceptance, and scores between 7 and 8 indicated very good acceptance (Kohli et al., 2023; Punfujinda et al., 2025a). Water was provided between tastings to minimize sensory fatigue. The samples were freshly prepared on the evaluation day and tested in triplicate following a randomized complete block design (RCBD) to ensure reliability (Namkham et al., 2024).

3.6. Production cost analysis

The economic feasibility of caramelized grated coconut was evaluated through a comprehensive cost analysis methodology. Production costs were calculated by determining the raw material expenses for each formula via the following formula: Raw material cost = actual ingredient weight (g) × price (USD)/total weight (g) (Punfujinda et al., 2024; Punfujinda et al., 2025b). The cost analysis compared the control formula (100% mature coconut) with the green papaya substitution formulas (25%, 50%, 75%, and 100% w/w), which presented favorable sensory characteristics. All ingredient costs were derived from current market prices in Pathum Thani Province, Thailand, during the research period (December 2024). This analysis provides insights into the economic viability of using green papaya as an alternative ingredient in traditional caramelized coconut production, considering both cost-effectiveness and sensory quality.

3.7. Ethical Declaration

The researchers observed full ethical standards in the conduct of the study following the study protocol assessments and standardized criteria by the institution. The research was conducted with participants following ethical considerations such as voluntary participation and an informed consent process. Prior to the sensory evaluation, the participants received a comprehensive briefing about the research objectives, ensuring fully informed and voluntary participation. Ethical considerations were paramount: participant identities were kept strictly confidential, no personal identification documents were collected, and the panelists were informed of their right to withdraw from the study at any time without consequences (Olaimat et al., 2023; Pasqualone et al., 2020; Punfujinda et al., 2024; Refardo et al., 2023). A validated questionnaire was utilized to evaluate the acceptability of caramelized coconut with green papaya substitution.

3.8. Data analysis

The effects of different ratios of green papaya substitution on the nutritional value of mature coconut were analyzed via one-way analysis of variance (ANOVA). For the caramelized coconut application in Thai desserts, an independent samples t



test was performed to compare two samples against the control formulas. All the statistical analyses were conducted via IBM SPSS Statistics software (version 22.0). The results are expressed as the means \pm standard deviations (SDs). Statistical significance was set at the 95% confidence level ($p < 0.05$), with p values less than 0.05 considered statistically significant.

4. Results and Discussion

4.1. Sensory evaluation of caramelized grated coconut

As shown in Table 2, the sensory evaluation of caramelized coconut with different levels of green papaya substitution revealed no significant differences ($p \geq 0.05$) among the control, GP25, and GP50 formulas in terms of all attributes except color, which received "very good" acceptance scores (7.33-7.86). This level of acceptance score aligned with the interpretation criteria, where scores between 7 and 8 indicated very good acceptance by the panellists. However, when the substitution level was increased to 75% (GP75) and 100% (GP100), the acceptance score decreased significantly ($p < 0.05$), particularly for texture, which decreased from 7.66 (control) to 6.00 (GP75) and 5.40 (GP100), respectively. The overall acceptability scores for GP75 and GP100 were significantly lower ($p < 0.05$) than those of the control, with scores of 6.53 and 6.13, respectively. Color did not significantly differ ($p \geq 0.05$) across all formulations. These results indicate that green papaya can be used as an effective substitute for mature coconut up to 50% without affecting sensory acceptance. The acceptance of the GP25 and GP50 formulas compared with the control can be attributed to the similar physical characteristics of green papaya to those of mature coconut, particularly its crispy texture and white color when grated (Thongyaem and Ketthongkam, 2021). Notably, the maintained taste and aroma characteristics at 50% substitution suggest that the mild flavor profile of green papaya does not interfere with the traditional sensory qualities of the product. The maintained sensory acceptance at these substitution levels aligns with previous research by Layim (2022), who reported that Thai dessert development could successfully incorporate healthier ingredients while preserving traditional sensory qualities. This finding is particularly significant, as it demonstrates the potential for developing healthier Thai dessert alternatives without compromising the authentic sensory experience that consumers expect. However, the significant decrease in acceptance scores at higher substitution levels (GP75 and GP100), particularly in terms of texture, may be due to the greater moisture content of green papaya than mature coconut (Bureau of Nutrition, 2018). This increased moisture likely affects the product's texture, leading to reduced crispiness and altered mouthfeel, which are crucial attributes in traditional Thai desserts (Chomshome et al., 2024). The consistent color acceptance across all formulations suggests that the natural white color of green papaya successfully mimics the visual appearance of grated coconut, which is an important factor in maintaining traditional characteristics, as noted by Mongkolvanit and Chartwong (2014) in their study of Thai dessert development. These findings align with current trends in Thai dessert development, where there is increasing emphasis on creating healthier alternatives while maintaining traditional sensory qualities that are crucial for consumer acceptance.

Table 2 Sensory evaluation scores of caramelized coconut prepared with different proportions of green papaya.

Characteristics	Control	GP25	GP50	GP75	GP100
Appearance	7.86 ^a ±0.74	7.80 ^a ±0.77	7.66 ^a ±0.61	6.93 ^b ±0.59	6.53 ^b ±0.74
Color ^{ns}	7.46±0.74	7.40±0.73	7.46±0.63	7.40±0.50	7.00±0.37
Smell	7.20 ^a ±0.56	7.13 ^a ±0.35	7.06 ^a ±0.70	6.60 ^b ±0.50	6.33 ^b ±0.61
Taste	7.60 ^a ±0.73	7.53 ^a ±0.63	7.46 ^a ±0.63	6.66 ^b ±0.72	6.26 ^b ±0.70
Texture	7.66 ^a ±0.48	7.53 ^a ±0.51	7.46 ^a ±0.51	6.00 ^b ±0.75	5.40 ^c ±0.50
Overall acceptability	7.53 ^a ±0.74	7.46 ^a ±0.74	7.33 ^a ±0.61	6.53 ^b ±0.63	6.13 ^b ±0.63

Control: 100% mature coconut; GP25, GP50, GP75, and GP100: Caramelized coconut prepared by substituting mature coconut with 25%, 50%, 75%, and 100% w/w green papaya, respectively. The results are expressed as the means \pm SDs ($n = 15$). Means within the same row followed by different superscript letters are significantly different at $p < 0.05$. ns denotes no significant difference at $p \geq 0.05$.

4.2. Nutritional properties of caramelized coconut

The results of the nutritional analysis presented in Table 3 revealed that green papaya substitution significantly affected the chemical composition ($p < 0.05$). As the substitution level increased, the moisture content increased significantly from 18.10% (control) to 44.50% (GP100), whereas the ash, protein, fat, total carbohydrate, and dietary fiber contents decreased. Notably, the fat content decreased substantially from 13.70% to 0.44% in GP100, whereas the dietary fiber content decreased from 6.02% to 3.58%. These compositional changes can be explained by the inherent nutritional differences between mature coconut and green papaya, as documented in the Food Composition Table of Thai Foods (Bureau of Nutrition, 2018). The higher moisture content in the substituted coconut than in the mature coconut (53.5%) reflects the naturally high moisture content of green papaya (93.2%). Similarly, the marked reduction in fat content aligns with the compositional data showing that green papaya contains significantly less fat (0.1%) than mature coconut does (28.7%), making it an excellent ingredient for developing reduced-fat products, as supported by Saeed et al. (2014) in their study of the potential of papaya as a healthier food alternative. The decrease in protein and carbohydrate contents in the substituted formulas corresponds with the lower natural levels of these nutrients in the green papaya (0.6% protein, 5.5% carbohydrate) than in the mature coconut (3.5% protein,

13.3% carbohydrate). While the dietary fiber content tends to decrease with increasing papaya substitution, Ali et al. (2011) noted that green papaya still provides beneficial dietary fiber and bioactive compounds that contribute to its nutritional value. These overall changes in nutritional composition, particularly the reduction in fat and carbohydrate contents while maintaining some fiber content, suggest that green papaya substitution could offer a healthier alternative in Thai dessert production, although with some nutritional trade-offs, as observed by Wynn (2017) in comparative studies of coconut products.

Table 3 Proximate analysis of caramelized coconut prepared with different proportions of green papaya.



Nutrition properties	Control	GP25	GP50	GP75	GP100
Moisture (%)	18.10 ^e ±0.10	23.45 ^d ±0.05	32.68 ^c ±0.18	39.12 ^b ±0.05	44.50 ^a ±0.10
Ash (%)	1.25 ^a ±0.05	1.12 ^b ±0.02	0.95 ^c ±0.01	0.67 ^d ±0.03	0.53 ^e ±0.03
Protein (%)	2.15 ^a ±0.03	1.85 ^b ±0.05	1.23 ^c ±0.03	0.78 ^d ±0.02	0.44 ^e ±0.01
Fat (%)	13.70 ^a ±0.10	9.85 ^b ±0.03	6.83 ^c ±0.03	3.21 ^d ±0.04	0.44 ^e ±0.01
Total carbohydrate (%)	64.80 ^a ±0.15	63.73 ^b ±0.38	58.31 ^c ±0.16	56.22 ^d ±0.07	54.09 ^e ±0.04
Dietary fiber (%)	6.02 ^a ±0.05	5.28 ^b ±0.04	4.65 ^c ±0.07	4.12 ^d ±0.02	3.58 ^e ±0.03

Control: 100% mature coconut; GP25, GP50, GP75, and GP100: caramelized coconut prepared by substituting mature coconut with 25%, 50%, 75%, and 100% w/w green papaya, respectively. The results are expressed as the means ± SDs (n = 3). Means within the same row followed by different superscript letters are significantly different at p<0.05.

4.3. Application of caramelized coconut in Thai desserts

The application of caramelized grated coconut in traditional Thai desserts represents an important aspect of this research. To demonstrate practical application, sticky rice with caramelized, grated coconut topping was selected as a model dessert. Table 4 presents the detailed ingredients, preparation methods, and visual documentation of the traditional Thai dessert prepared with both the control and modified versions of caramelized grated coconut. The formula demonstrates how green papaya-substituted caramelized coconut can be integrated into traditional Thai dessert making while preserving authentic preparation techniques.

Table 4 Application of green papaya as a substitute for caramelized coconut in a Thai dessert.

Ingredients, preparation method	Visual presentation of traditional caramelized grated coconut topping (control)	Visual presentation of caramelized grated coconut topping (GP50)
<p>Sticky rice with caramelized grated coconut topping</p> <p>Ingredients: White glutinous rice, black glutinous rice, coconut milk, sugar, salt, and caramelized grated coconut</p> <p>Methods: 1. Soak white and black glutinous rice together in water for approximately 6 hours. 2. Mix coconut milk, sugar, and salt in a pot. Bring to a gentle boil. 3. Steam the soaked glutinous rice over high heat for 30 minutes. While still hot, transfer the steamed rice into the coconut milk mixture from step 2. 4. Let the mixture rest for 20 minutes to allow the rice to absorb the coconut milk, stirring occasionally to ensure even distribution. 5. Serve the sticky rice topped with caramelized grated coconut.</p>		

The formula and preparation methods for sticky rice with caramelized grated coconut topping were adapted from Chumkaew (2020).

Table 5 shows the sensory evaluation comparing sticky rice with traditional caramelized coconut topping (control) and 50% green papaya substitution (GP50). The results revealed no significant differences (p≥0.05) in any of the attributes: appearance (7.72±0.70 and 7.66±0.74), color (7.54±0.78 and 7.46±0.81), smell (7.48±0.64 and 7.44±0.67), taste (7.38±0.80 and 7.18±0.84), texture (7.40±1.03 and 7.26±0.75), or overall acceptability (7.50±0.78 and 7.28±0.85). Both formulations received scores within the "very good" acceptance range (7–8) for all attributes, with control scores ranging from 7.38–7.72 and GP50 scores ranging from 7.18–7.66. These results demonstrate that using 50% green papaya as a substitute for caramelized coconut when it is served with sticky rice does not affect consumer acceptance, maintaining consistently very good acceptance levels comparable to those of the traditional formula. The successful application in sticky rice desserts aligns with the findings of



Layim (2022) regarding the importance of maintaining traditional sensory characteristics when developing healthier Thai desserts. The comparable acceptance scores across all attributes, particularly texture and taste, suggest that the modified caramelized grated coconut effectively preserves the traditional sensory experience that consumers expect, as noted by Mongkolvanit and Chartwong (2014) in their study of Thai dessert development. Furthermore, these results demonstrate the versatility of the developed product in actual dessert applications, indicating its potential for commercial adoption while meeting both traditional quality standards and modern health-conscious consumer preferences (Chomshome et al., 2024; Jairai et al., 2023).

Table 5 Sensory evaluation of sticky rice dessert prepared with traditional and green papaya-substituted caramelized grated coconut topping.

Characteristics	Sticky rice with caramelized grated coconut topping from control	Sticky rice with caramelized grated coconut topping from GP50
Appearance ^{ns}	7.72±0.70	7.66±0.74
Color ^{ns}	7.54±0.78	7.46±0.81
Smell ^{ns}	7.48±0.64	7.44±0.67
Taste ^{ns}	7.38±0.80	7.18±0.84
Texture ^{ns}	7.40±1.03	7.26±0.75
Overall acceptability ^{ns}	7.50±0.78	7.28±0.85

The results are expressed as the means ± SDs (n = 50). ns denotes no significant difference at p≥0.05.

4.4. Analysis of the production cost of caramelized grated coconut

The production costs of caramelized coconut with different levels of green papaya substitution are presented in Table 6. The control formula had the highest production cost, at 5.27 USD. As the proportion of green papaya substitution increased, the production costs progressively decreased. The GP25, GP50, GP75, and GP100 formulas presented production costs of 4.33, 3.36, 2.42, and 1.45 USD, respectively. Compared with those of the control formula, the production cost reductions were 17.83%, 36.24%, 54.07%, and 72.48% for GP25, GP50, GP75, and GP100, respectively. Compared with the control formula, the GP100 formula resulted in the greatest cost reduction of 72.48%. This significant cost reduction reflects the market price dynamics of agricultural commodities (Vercammen, 2012), where the lower price of green papaya is attributed to its abundant year-round cultivation and harvest in Thailand, particularly in the northeastern region, where it is a major economic crop. In contrast, mature coconut often faces price fluctuations due to seasonal availability and growing conditions. The economic advantage is particularly noteworthy for the GP50 formula, which achieved a 36.24% cost reduction while maintaining sensory acceptance comparable to that of the traditional formula. This finding aligns with current trends in Thai dessert development, which emphasize both cost efficiency and product quality (Layim, 2022). From a commercial perspective, this cost reduction could provide significant competitive advantages for SMEs in the Thai dessert industry, especially during periods of high coconut prices (Chomshome et al., 2024). The combined benefits of reduced production costs and maintained product quality suggest strong potential for commercial adoption of this modified formula.

Table 6 Production cost comparison of caramelized coconut with different levels of green papaya substitution.

Samples	Production cost (USD)	Production cost reduction (%)
Control	5.27	-
GP25	4.33	17.83
GP50	3.36	36.24
GP75	2.42	54.07
GP100	1.45	72.48

Control: 100% mature coconut; GP25, GP50, GP75, and GP100: Caramelized coconut prepared by substituting mature coconut with 25%, 50%, 75%, and 100% w/w green papaya, respectively. All ingredient costs were based on market prices in Pathum Thani Province, Thailand (December 2024).

5. Conclusions

This research demonstrated the successful development of caramelized coconut using green papaya as a substitute for mature coconut. The results indicated that green papaya could effectively replace mature coconut at various substitution percentages (25%, 50%, 75%, and 100%). Sensory evaluation by expert panels revealed that the 50% substitution (GP50) formula achieved acceptance scores comparable to those of the control formula in terms of appearance, color, smell, taste, texture, and overall acceptability. Nutritional analysis revealed that green papaya substitution resulted in products with lower fat and carbohydrate contents while maintaining adequate fiber content. This modification aligns with current consumer trends toward healthier food options. The production cost analysis demonstrated a significant cost reduction, with the GP50 formula resulting in a 36.24% decrease in raw material costs compared with the control formula.

Furthermore, application testing in sticky rice desserts confirmed that the modified caramelized coconut could be successfully integrated into traditional Thai desserts while maintaining authentic characteristics. This innovation provides a



practical solution for addressing both the availability and cost challenges associated with mature coconut in Thai dessert production while potentially offering healthier alternatives to consumers.

Acknowledgment

The authors gratefully acknowledge the Faculty of Home Economics Technology, Rajamangala University of Technology Thanyaburi, for providing laboratory facilities and research space for this study.

Ethical considerations

We confirm that we have correctly followed the ethical policies for this study, which includes human subjects, in addition to confirming the consent of all the respondents involved.

Conflict of interest

The authors declare that they have no conflicts of interest.

Funding

This research did not receive any financial support.

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