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Physicochemical and Sensory Properties of Coconut Flour Cake

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Abstract

The demand for healthier and functional baked goods has led to the exploration of alternative flours with higher nutritional benefits. This study investigates the potential of coconut flour as an innovative ingredient in butter cake formulations, focusing on its impact on physicochemical and sensory properties. Coconut flour, valued for its high dietary fiber content (60.9%), unique flavour, and ability to enhance the nutritional profile of baked goods, was evaluated in formulations with 10%, 20%, and 30% coconut flour substitutions alongside wheat flour. Physicochemical analyses revealed that increasing coconut flour content influenced moisture retention, texture, color, and pH, with higher substitution levels resulting in denser structures and distinct browning effects during baking. For example, the pH decreased from 8.30 (control) to 7.78 (30% substitution), and firmness increased from 344.88 g (control) to 393.2 g (20% substitution). Sensory evaluations conducted with 50 panelists highlighted that cakes containing 10% and 20% coconut flour achieved the best balance of appearance (7.58), flavor (7.58), texture (7.22), and overall acceptability (7.62), significantly outperforming the control. These findings demonstrate that coconut flour can elevate the nutritional value and sensory appeal of cakes without compromising consumer satisfaction. This study is timely, given the rising popularity of functional foods and consumer interest in natural ingredients that contribute to well-being. By addressing the technical challenges of incorporating coconut flour, this research offers valuable insights for food technologists and product developers aiming to create healthier, innovative bakery products that align with current food trends. Future studies should explore shelf-life stability and formulation optimization for large-scale bakery applications.

1. Introduction

Coconut (Cocos nucifera L.) is a versatile and nutrient-rich crop, widely valued for its high dietary fiber, protein, and carbohydrate content. Coconut flour, a by-product of virgin coconut oil production, despite its high fiber and protein content, coconut flour presents formulation challenges due to its high absorbency and impact on texture. Limited studies have investigated its optimal substitution levels in butter cakes, offering health benefits such as improved digestive health and a lower glycemic index. However, its high absorbency and distinct flavor profile pose challenges in achieving desirable texture and sensory attributes in food products. These challenges necessitate modifications in recipe formulations, such as blending coconut flour with wheat flour or adjusting ingredient ratios, to balance sensory qualities while maintaining consumer acceptability.

Existing research supports the functional benefits of coconut flour. [1] demonstrated that Maillard reactions during baking enhance browning effects and sensory appeal in products containing coconut flour. [2] highlighted the nutritional and sensory benefits of replacing wheat flour with coconut flour in bread formulations. Similarly, [3] found that coconut flour enhances the dietary fiber content of cakes while maintaining acceptable sensory attributes. Despite these findings, challenges such as the flavor intensity and high absorbency of coconut flour remain, often requiring innovative recipe adjustments to optimize product quality. Furthermore, there is limited research specifically addressing the use of coconut flour in butter cake formulations and the effects of varying substitution levels on physicochemical and sensory properties.

This study aims to bridge this research gap by evaluating how different percentages of coconut flour influence the physicochemical properties of butter cakes, including moisture content, pH, texture, and color. Additionally, sensory attributes such as flavor, texture, and overall acceptability will be assessed to determine consumer preferences. By addressing these aspects, this study seeks to provide valuable insights for food technologists and product developers aiming to create healthier and more appealing bakery products that align with current trends favoring functional foods and natural ingredients.

2. Material and Methods

2.1 Material

The raw materials used for the production of coconut flour cake were sourced from a local supermarket in Pagoh. These included coconut flour, wheat flour, castor sugar, eggs, vegetable oil, condensed milk, evaporated milk, baking powder, vanilla essence, and salt. The specific measurements of each ingredient are outlined in Table 1. To ensure consistent results, commercially available coconut flour was sieved to a uniform particle size before use.

Cakes were stored in high-density polyethylene (HDPE) bags to retain their freshness and texture. Storage conditions were standardized that cakes were kept at ambient room temperature (25 ± 2°C) with a relative humidity of 60-70%. No refrigeration was used during the analysis period to simulate typical storage conditions for bakery products. These measures ensured stability and preserved the quality of the cakes for subsequent physicochemical and sensory analyses.

2.2 Preparation of coconut flour cake

The preparation of coconut flour cake involved using commercially available coconut flour sieved to a uniform particle size. A standardized batter was made by mixing coconut flour with sugar, eggs, flour, baking powder, and water in a planetary mixer for 5 minutes. The batter was poured into pre-greased molds and baked at 180 °C for 25 minutes. After cooling at room temperature for 30 minutes, the cakes were removed from the molds and stored in HDPE bags to retain freshness and texture, ensuring consistency for further analyses.

Table 1 Formulation of coconut flour cake

INGREDIENTS	MEASUREMENTS (g)	COCONUT FLOUR (%)
Wheat flour	100	-
Coconut flour	-	10% (10g) 20% (20g) 30% (30g)
Castor sugar	50	-
Vegetable oil	40	-
Condensed milk	30	-
Evaporated milk	30	-
Eggs	80	-
Baking powder	5	-
Vanilla essence	5	-
Salt	2	-

2.3 Analysis on Physicochemical Properties

2.3.1 Moisture content analysis

Moisture content was determined by drying 1 g of each sample at 160°C for 8 minutes in a thermostatically controlled oven until a constant weight was obtained. Values were recorded as mean ± standard deviation from triplicate measurements. The final moisture content of the samples was measured using a Thermo Scientific Eutech PH 700 moisture analyzer.

2.3.2 Colour

The L* (lightness), a* (red-green spectrum), and b* (yellow-blue spectrum) color values of the coconut flour cake were assessed using a calibrated colorimeter, following the protocol outlined [4]. This approach ensured consistent data collection and precise representation of the sample's color characteristics.

2.3.3 pH value

Ten grams of coconut cake samples were mixed with 90 mL of distilled water in a 250 mL conical flask to prepare a suspension for pH analysis, following the method [18]. The pH was measured using a calibrated pH meter (Thermo Fisher Scientific, Ottawa, ON, Canada) with standard buffer solutions (pH 4.0 and pH 7.0) to ensure accuracy. The electrode was rinsed with distilled water before immersion in the suspension, and readings were recorded after stabilization. All measurements performed in triplicate for reliability.

2.3.4 Texture profile analysis

The textural properties of coconut flour cakes, including firmness and springiness, were evaluated using a texture analyzer (TA-XT Plus, Stable Micro Systems, UK), equipped with a 35 mm aluminum cylinder probe. The analyzer was set to operate at 2.0 mm/s with 20% compression strain and a 5-second recovery interval between compressions. Firmness was measured as the peak force (g) during initial compression, while springiness (%) was determined by the sample's ability to recover its shape after compression. Each sample was tested in triplicate, and results were reported as mean ± standard deviation, ensuring accuracy and reproducibility.

2.4 Sensory evaluation

Measurements were also taken of the baked cakes' weights and specific volumes. The symmetry, as well as the crumb and crust properties, of the cakes that had coconut flour added were assessed and noted. The color, taste, texture, appearance and overall acceptance of the cakes were assessed organoleptically. Additionally, a 9-point hedonic rating test was used to gauge how acceptable cakes made with coconut flour were. 50 participants were given one slice of cake from each lot as randomly coded samples. The items will be tasted by the panelists, who will then rate them [3]. Through a pass-through compartment, samples were given to each panelist in a monadic sequential order. Samples were supplied on distinct foam plates with tap water to rinse the pallet in between samples and labels with three-digit blinding codes. The following characteristics were chosen for assessment: appearance, texture, taste, odour, colour and overall acceptance. The questionnaire is given in google form.

3. Result and discussion

3.1 Physicochemical Analysis

3.1.1 Moisture content, Colour, pH, Texture

Table 2 below shows the result of moisture content, colour, pH and texture analysis for coconut flour cake with different formulations of coconut flour.

The moisture content of the coconut flour cakes showed slight variations across the formulations, with no statistically significant differences observed ($p = 0.175$). The control sample exhibited the highest moisture content at 24.28 ± 1.09%, while the 10% coconut flour formulation (F1) showed a slight reduction to 23.39 ± 1.48%. Interestingly, formulations with 20% (F2) and 30% (F3) coconut flour substitution demonstrated increased moisture retention, with values of 25.56 ± 1.18% and 25.04 ± 0.47%, respectively. This trend can be explained by the high water absorption capacity of the fiber present in coconut flour, which enhances water retention at higher substitution levels. Similar observations were reported by [22], who noted that the high water-binding capacity of fiber-enriched flours improves moisture retention in baked goods. [18] also highlighted the role of dietary fiber in stabilizing water content in food formulations. The practical implications of these findings are significant, as maintaining stable moisture levels can preserve the freshness and extend the shelf life of cakes, making them less prone to drying out during storage. These results align with the findings [23], who observed improved water-holding capacity in fiber-enriched bakery products, thereby enhancing their overall quality and stability.

Table 2 summary results for moisture content, colour, pH and texture of coconut flour cake

Sample	Colour			Moisture (%)	pH	Texture	
	L*	A*	B*			Firmness (g/sec)	Springiness (%)
Control	57.7233 ± 0.0058c	8.2333 ± 0.0058c	47.8833 ± 0.0058b	24.287± 1.098a	8.307± 0.012a	344.88 ± 5.94a	50.741 ± 0.813a
F1	58.3667± 0.0058b	13.9567± 0.0058 a	48.3467± 0.0058a	23.390± 1.482a	8.053± 0.006b	380.37± 14.53a	48.110± 0.507a
F 2	51.0933 ± 0.0058d	13.2967 ± 0.0058b	39.6033 ± 0.0058d	25.557± 1.181a	7.737± 0.015c	393.2 ± 56.2a	47.04± 2.43a
F 3	60.67± 0.01a	5.42667± 0.01528d	40.33± 0.01c	25.040± 0.468a	7.783± 0.037c	357.4± 20.6a	47.467± 1.525a

Colour analysis revealed that coconut flour substitution significantly influenced the lightness (L*), redness (a*), and yellowness (b*) values of the cakes, with *p*-values below 0.05 for all parameters. Lightness values increased slightly in the 10% formulation (F1), from 57.72 ± 0.01 in the control to 58.37 ± 0.01, before decreasing to 51.09 ± 0.01 in F2 and then rising again to 60.67 ± 0.01 in F3. The increase in lightness at higher substitution levels can be attributed to the reflective properties of coconut flour, while the decrease observed in F2 may result from intensified browning reactions caused by the fiber and sugar content of the flour.[1] similarly reported that coconut flour influences browning reactions during baking, driven by its fiber composition. Redness (a*) was highest in F1 at 13.95 ± 0.01 but dropped to 5.43 ± 0.01 in F3. Similarly, yellowness (b*) peaked in F1 at 48.34 ± 0.01 but decreased to 39.60 ± 0.01 and 40.33 ± 0.01 in F2 and F3, respectively. The reduction in redness and yellowness at higher substitution levels can be linked to the dilution effect of the fiber in coconut flour, which reduces the intensity of the pigments in the final product. [23] noted similar results, suggesting that higher fiber content alters Maillard reactions, leading to less vibrant colours. While moderate levels of coconut flour substitution improve the visual appeal of the cakes, excessive levels may result in darker or duller products, potentially affecting consumer preferences.

The pH of the cakes decreased significantly ($p<0.05$) with increasing levels of coconut flour, with a p-value of 0.01 confirming these changes. The control cake exhibited the highest pH value of 8.30, while formulation 3 had the lowest pH of 7.78. This reduction was attributed to the acidic nature of coconut flour, which contains organic acids and compounds that influence the final product's pH which contribute to flavour development and microbial stability, potentially extending shelf life, as outlined by Kim et al. Lower pH levels may enhance microbial stability and extend shelf life while contributing to subtle flavour changes. These findings align with observations by [20] and [23]., who noted similar trends in baked goods incorporating alternative flours.

The texture of the cakes was also influenced by coconut flour substitution, although the changes in firmness and springiness were not statistically significant ($p = 0.20$). Firmness increased from 344.88 ± 5.94 g in the control to 380.37 ± 14.53 g in F1 and 393.2 ± 56.2 g in F2 before slightly decreasing to 357.4 ± 20.6 g in F3. The increase in firmness with moderate substitution levels can be attributed to the water-binding capacity of coconut flour, which creates a denser structure. However, the slight decrease in firmness observed in F3 suggests that excessive fiber content may disrupt the structural integrity of the cake, a phenomenon also reported by Jafari in 2020. Springiness, which reflects the elasticity of the cakes, showed a slight decline across all formulations, decreasing from 50.74% in the control to 48.11% in F1, 47.04% in F2, and 47.47% in F3. The reduction in springiness can be attributed to the interference of coconut flour's fiber with the gluten network, which limits elasticity. [21] also observed that high fiber content in gluten-free bakery products decreases springiness due to restricted gluten formation. From a sensory perspective, the coarser texture and reduced elasticity in F3 may negatively impact consumer acceptance, while formulations with 10% and 20% coconut flour substitution achieved a better balance between firmness and springiness, aligning with the preferences expressed by sensory panellists.

The findings of this study are consistent with previous research on the utilization of coconut flour in bakery products. Kumar in 2018 emphasized that moderate substitution levels of coconut flour, particularly in the range of 10–20%, optimize the physicochemical and sensory properties of cakes, while higher levels negatively affect texture and flavour. Similarly, [23] found that excessive coconut flour substitution reduces consumer acceptance due to undesirable changes in texture and colour. [3] highlighted that coconut flour enhances the nutritional profile of cakes while maintaining consumer acceptability at moderate substitution levels. This study builds on these findings by demonstrating the specific effects of coconut flour on butter cake formulations, providing additional insights into its role as a functional ingredient in bakery products.

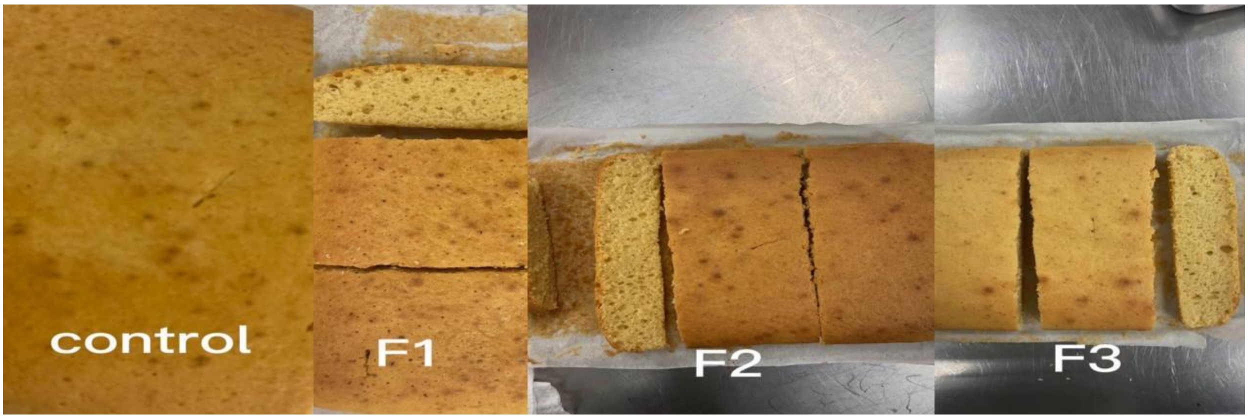

Fig. 1 Different browning effect of control cake, F1, F2 and F3

3.2 Sensory evaluation test

A sensory test on 4 samples of coconut flour cake with different formulation of coconut flour usage was carried out for 50 panellists. The sensory attributes evaluated included appearance, colour, odour, texture, taste and overall acceptance. Each attribute was determined by a 9-point hedonic scale. The sensory evaluation of coconut flour cake was conducted to assess consumer acceptance of cakes formulated with varying percentages of coconut flour (10%, 20%, and 30%). The parameters analysed included appearance, colour, odor, texture, taste, and overall acceptance. Results showed notable differences across the formulations.

Table 2 Sensory results of coconut flour cake

Sample	Appearance	Colour	Odour	Texture	Taste	Overall acceptance
Control	$4.880{\pm}2.616^b$	$5.040{\pm}2.571^b$	$4.880{\pm}2.760^b$	$4.820{\pm}2.472^b$	$5.120{\pm}2.387^b$	$4.920{\pm}1.085^b$
F1	$7.580{\pm}1.444^a$	$7.360{\pm}1.758^a$	$7.640{\pm}1.467^a$	$7.220{\pm}1.730^a$	$7.580{\pm}1.472^a$	$7.620{\pm}1.510^a$
F2	$7.480{\pm}1.568^a$	$7.320{\pm}1.778^a$	$7.360{\pm}1.613^a$	$7.140{\pm}1.519^a$	$7.360{\pm}1.626^a$	$7.540{\pm}1.432^a$
F 3	$6.980{\pm}1.964^a$	$6.940{\pm}1.963^a$	$7.260{\pm}1.936^b$	$6.600{\pm}2.030^a$	$7.320{\pm}1.708^a$	$7.100{\pm}1.776^a$

Sensory evaluation revealed that moderate levels of coconut flour significantly enhanced the sensory qualities of cakes. In terms of appearance, the substitution of coconut flour significantly enhanced the visual appeal of the cakes. The control sample scored the lowest for appearance at 4.88, while formulations with 10% and 20% coconut flour substitution received higher scores of 7.58 and 7.48, respectively, indicating improved visual quality. However, the 30% substitution resulted in a slightly lower score of 6.98, suggesting that excessive coconut flour incorporation may adversely affect the appearance. Sensory evaluation revealed that the formulation with 30% coconut flour substitution (F3) was the least favoured by panellists in terms of overall sensory attributes, including texture, flavour, and colour. The overall acceptability score for F3 was significantly lower compared to the 10% (F1) and 20% (F2) formulations. While moderate levels of substitution (10–20%) achieved higher sensory scores due to improved nutritional benefits without compromising sensory quality, the excessive substitution of coconut flour at 30% negatively impacted consumer preferences.

For colour, the control scored 5.04, while formulations with 10% and 20% coconut flour achieved higher scores of 7.36 and 7.32, respectively, indicating improved coloration. However, the 30% substitution scored slightly lower, as panellists noted darker or uneven coloration likely due to the higher fiber content. Odour improved significantly with the inclusion of coconut flour, with the control scoring 4.88 and formulations with 10%, 20%, and 30% substitution receiving scores of 7.64, 7.36, and 7.26, respectively, reflecting the aromatic properties of coconut flour. The decline in colour attributes also contributed to the reduced sensory scores of F3. As highlighted in the colour analysis, the redness (a*) and yellowness (b*) values decreased significantly at 30% coconut flour substitution, resulting in a duller appearance that may have been perceived as less appetizing. [23] reported similar findings, emphasizing that darker and less vibrant baked products are often associated with lower quality in sensory evaluations. The pale and less uniform colour of F3 likely detracted from its visual appeal, further influencing the overall acceptability of this formulation.

Texture scores were lowest for the control at 4.82, while 10% and 20% substitutions scored higher at 7.22 and 7.14, respectively, offering a desirable texture. The 30% formulation scored slightly lower at 6.60, potentially due to a coarser texture from increased fiber content. Taste scores followed a similar trend, with the control scoring 5.12, while 10% and 20% substitutions achieved 7.58 and 7.36, respectively, reflecting enhanced flavour. The 30% substitution scored slightly lower at 7.10, likely due to a stronger, less balanced taste. For overall acceptance, the control scored 4.92, while 10% and 20% formulations were the most preferred, with scores of 7.62 and 7.54, respectively. The 30% substitution, though slightly less favoured, still received a respectable score of 7.10.

The decline in sensory scores for F3 can primarily be attributed to the texture of the cakes. The high fiber content in the 30% coconut flour formulation contributed to a denser, coarser crumb structure, which deviated from the soft and springy texture expected in butter cakes. As noted in the texture analysis, the firmness of F3 slightly decreased compared to F2, yet it remained significantly higher than the control and F1. Additionally, the reduction in springiness due to the disruption of the gluten network in F3 likely contributed to a less desirable mouthfeel. These findings align with the observations of [19], who reported that high levels of fiber in baked goods often result in a gritty texture and reduced elasticity, negatively influencing consumer perception.

These findings align with studies by [20] and [23], which reported enhanced sensory attributes with coconut flour substitution levels up to 20%, beyond which acceptability declined due to textural and flavour changes. The results highlight the potential of 10% and 20% coconut flour as optimal substitution levels, balancing improved sensory qualities and consumer acceptance. This demonstrates the feasibility of incorporating coconut flour as a functional ingredient to enhance the appeal of baked products.

4. Conclusion

This study investigated the impact of coconut flour substitution on the physicochemical properties and sensory attributes of butter cakes, providing valuable insights into its potential as a functional ingredient in bakery products. The results demonstrate that coconut flour substitution significantly can be successfully incorporated into butter cake formulations, improving nutritional value while maintaining consumer acceptability that influences cake quality, with varying effects depending on the substitution level. While moderate levels (10% and 20%) of coconut flour substitution enhanced the nutritional profile of the cakes without drastically compromising sensory attributes, higher substitution levels (30%) resulted in notable declines in sensory acceptability, primarily due to changes in texture, flavour, and colour. The mechanisms underlying these changes were closely linked to the physicochemical properties of coconut flour. Its high fiber content, while beneficial for moisture retention and dietary fiber enrichment, led to a denser crumb structure and reduced elasticity, which negatively impacted texture and mouthfeel at higher substitution levels. Furthermore, the pronounced nutty and earthy flavour of coconut flour became dominant in the 30% formulation, overshadowing the buttery and sweet notes that are characteristic of traditional butter cakes. The colour of cakes with higher substitution levels was also less vibrant, as the fiber content influenced Maillard reactions and pigmentation during baking, leading to darker and duller appearances. Statistical analysis confirmed the significance of these findings, with p-values below 0.05 for most sensory and physicochemical parameters. Notably, the differences in overall acceptability between the 10% and 20% formulations were not statistically significant, indicating that both levels are within the optimal range for balancing the nutritional benefits and sensory qualities of coconut flour cakes. Conversely, the significant decline in sensory scores for the 30% formulation highlights the importance of limiting substitution levels to maintain consumer appeal.

Coconut flour's functional benefits, including its gluten-free nature and high dietary fiber content, position it as a desirable ingredient for health-conscious consumers. However, its strong flavour and impact on texture and colour require careful formulation adjustments to optimize consumer acceptance. By blending coconut flour with wheat flour at moderate substitution levels and exploring complementary ingredients or baking techniques, product developers can create bakery products that align with modern trends in functional and health-focused foods. In conclusion, this study provides actionable insights into the utilization of coconut flour in butter cakes, emphasizing the importance of balancing its nutritional and sensory attributes. The findings offer a foundation for future research into recipe optimization and consumer-driven product development, further advancing the integration of coconut flour into innovative bakery formulations and should explore shelf-life stability, ingredient interactions, and large-scale production feasibility.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Khairin Najwa Kamarul Azam, Hatijah Basri;* ***data collection:*** *Hatijah Basri;* ***analysis and interpretation of results:*** *Khairin Najwa Kamarul Azam, Hatijah Basri;* ***draft manuscript preparation:*** *Khairin Najwa Kamarul Azam, Hatijah Basri. All authors reviewed the results and approved the final version of the manuscript.*

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