Mauliza et al. (2026). Vol. 3, Issue 1. pp 1-5
https://doi.org/10.63197/nahi.v3i1.100

Nutrition and Health Insights

Original Research

Open Access

Effect of Nipah fruit (*Nypa Fruticans*) substitution on bioactive compounds and sensory properties of functional pudding

Pengaruh substitusi buah Nipah (Nypa Fruticans) terhadap senyawa bioaktif dan sifat sensoris puding fungsional

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Abstract

Background: Nipah fruit (*Nypa fruticans*) is an underused mangrove fruit containing flavonoid and phenolic compounds. Objective: To evaluate sensory characteristics and total flavonoid and phenolic contents of pudding with different nipah substitution levels. Methods: A completely randomized experiment was conducted in Aceh, Indonesia, in August 2024. Three formulations containing 10%, 20%, and 30% nipah fruit were prepared in triplicate. Twenty-five moderately trained panelists evaluated color, aroma, texture, and taste using a hedonic scale. Total flavonoids and phenolics were quantified by UV-Vis spectrophotometry using quercetin and gallic acid standards. Data were analyzed by one-way ANOVA and Duncan's test. Results: Substitution significantly affected texture (p=0.007), flavonoids (p=0.002), and phenolics (p<0.001), but not color, aroma, or taste. The 20% formulation had the highest texture score (4.41), whereas the 30% formulation had the highest flavonoid (9.99 mg/L) and phenolic content (80.25 mg GAE/100 g). Conclusion: Nipah fruit increased measured bioactive compounds while maintaining acceptable sensory properties. Clinical glycemic-response studies are needed before health recommendations are made.
Keywords: Hedonic acceptance; Total flavonoids; Total phenolics; Mangrove palm; Product development

Abstrak

Latar Belakang: Buah nipah (*Nypa fruticans*) merupakan buah mangrove yang belum banyak dimanfaatkan dan mengandung flavonoid serta fenolik. Tujuan: Menganalisis karakteristik sensoris serta kandungan flavonoid dan fenolik total puding pada tingkat substitusi buah nipah yang berbeda. Metode: Penelitian eksperimental dengan Rancangan Acak Lengkap dilaksanakan di Aceh pada Agustus 2024. Tiga formulasi, yaitu substitusi 10%, 20%, dan 30%, dibuat dengan tiga pengulangan. Sebanyak 25 panelis agak terlatih menilai warna, aroma, tekstur, dan rasa dengan skala hedonik. Flavonoid dan fenolik total dianalisis menggunakan spektrofotometri UV-Vis dengan standar kuersetin dan asam galat. Data dianalisis menggunakan ANOVA satu arah dan uji Duncan. Hasil: Substitusi berpengaruh signifikan terhadap tekstur (p=0,007), flavonoid (p=0,002), dan fenolik (p<0,001), tetapi tidak terhadap warna, aroma, atau rasa. Formulasi 20% memiliki skor tekstur tertinggi (4,41), sedangkan formulasi 30% memiliki flavonoid (9,99 mg/L) dan fenolik tertinggi (80,25 mg GAE/100 g). Kesimpulan: Buah nipah meningkatkan senyawa bioaktif terukur dengan mempertahankan sifat sensoris yang dapat diterima. Uji respons glikemik masih diperlukan sebelum rekomendasi kesehatan diberikan.
Kata Kunci: Penerimaan hedonik; Flavonoid total; Fenolik total; Palma mangrove; Pengembangan produk

(Received 2026; Accepted after revision 2026; First published online May 2026)

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Nutrition and Health Insights

Publisher: CV. Dapu Aceh Publishing

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from impaired insulin secretion, insulin action, or both. It remains a major public health concern: the International Diabetes Federation estimated that hundreds of millions of adults were living with diabetes in 2024 and projected a substantial increase by 2050.[1] Effective management therefore requires an integrated approach that includes medical nutrition therapy, physical activity, medication when indicated, and sustained self-management support.[2]

Food-based strategies are increasingly directed toward nutrient-dense products that are acceptable, practical, and compatible with long-term dietary patterns. Functional foods are generally developed to provide physiological benefits beyond basic nutrition, but credible product development requires evidence of composition, technological feasibility, sensory acceptability, safety, and ultimately efficacy in humans.[3] Consequently, the designation of a product as functional should be based on measured characteristics and should not be interpreted as proof of disease prevention or treatment.

Plant-derived polyphenols, including flavonoids and other phenolic compounds, are frequently investigated as functional ingredients. Experimental evidence suggests that flavonoids may influence oxidative stress, glucose transport, insulin signaling, hepatic glucose metabolism, and pancreatic beta-cell protection.[4] Phenolic compounds may also affect carbohydrate digestion and postprandial glucose handling through enzyme inhibition and antioxidant or anti-inflammatory pathways.[5,6] Nevertheless, the biological effects observed in extracts or model systems cannot be assumed to occur after consumption of a processed food because food-matrix interactions, processing losses, dose, and bioavailability can modify the response.[6,11]

Nypa fruticans Wurmb, commonly known as nipa or nipah, is a mangrove palm distributed in tidal estuaries of tropical Asia. Its fruit is locally consumed and the plant has been used for food, beverages, household products, and other community applications.[7,8] Reviews and laboratory studies have reported phenolic, flavonoid, tannin, and fiber components in different parts of the plant, while a study of nipah fruit extract identified measurable total flavonoid and phenolic contents.[7,9,10] These characteristics support investigation of nipah fruit as a local ingredient, although evidence from finished food products remains limited.

In Aceh, young nipah fruit is commonly added to sweet drinks or desserts. Such use demonstrates cultural familiarity but may involve substantial added sugar. Pudding offers an alternative food matrix because it is simple to prepare, has a soft texture, and can incorporate fruit pulp while controlling the quantity of added sweetener. Product acceptance is essential, however, because increasing fruit solids may change color, aroma, taste, and gel structure. Agar concentration, water content, and fruit-derived fiber can interact to alter firmness and palatability.[10,13]

Previous research has described the phytochemical potential of nipah and the sensory effects of adding plant ingredients to gelled desserts, but comparative evidence on substitution levels in nipah pudding is scarce.[7-10,14] The novelty of this study is the simultaneous evaluation of sensory acceptance and two bioactive-compound indicators across graded nipah fruit formulations. This study therefore aimed to determine the effects of 10%, 20%, and 30% nipah fruit substitution on the sensory properties, total flavonoid content, and total phenolic content of pudding.

Methods

Study Design, Setting, and Ethics

This laboratory-based experimental study used a completely randomized design with one treatment factor: the proportion of nipah fruit in the pudding formulation. Three treatment levels were evaluated—10% (R1), 20% (R2), and 30% (R3)—and each formulation was prepared in three independent replications. The study was conducted in August 2024. Sensory evaluation took place at the Organoleptic Laboratory, Department of Nutrition, Poltekkes Kemenkes Aceh, and chemical analyses were performed at the Food and Agricultural Product Analysis Laboratory, Faculty of Agriculture, Universitas Syiah Kuala, Aceh, Indonesia. Ethical approval was obtained from the Health Research Ethics Committee of Poltekkes Kemenkes Aceh (No. DP.04.03/12.7/239/2024).

Ingredients and Pudding Preparation

The pudding ingredients were fresh nipah fruit pulp, low-fat liquid milk, plain agar powder, low-calorie sweetener, and mineral water. Cooking equipment included a blender, digital scale, measuring cup, saucepan, stove, mixing bowl, ladle, and pudding molds. The formulation was designed so that the combined amount of fruit pulp and water remained constant while the proportion of fruit increased (Table 1).

The fruit pulp was weighed according to the treatment, blended with the assigned volume of water until homogeneous, and transferred to a saucepan. Low-fat milk, agar powder, and low-calorie sweetener were added. The mixture was heated with continuous stirring until boiling, poured into molds, cooled, and allowed to set before evaluation.

Table 1. Formulation of nipah fruit pudding by treatment

Ingredient	R1 (10%)	R2 (20%)	R3 (30%)
Nipah fruit pulp (g)	200	400	600
Water (mL)	800	600	400
Low-fat milk (mL)	1,000	1,000	1,000
Plain agar powder (g)	14	14	14
Low-calorie sweetener (g)	20	20	20

Sensory Evaluation

Twenty-five moderately trained panelists evaluated the three coded formulations. The assessed attributes were color, aroma, texture, and taste. Samples were served under comparable conditions with drinking water provided for palate cleansing. Panelists recorded their degree of liking on a five-point hedonic scale, with higher scores indicating greater acceptance. The procedures followed standard principles for affective sensory testing and randomized sample presentation.[15]

Total Flavonoid and Phenolic Analyses

Pudding samples were prepared using 95% ethanol for spectrophotometric analysis. Total flavonoid content was quantified with a quercetin calibration curve at 6, 8, 10, 12, and 14 mg/L and absorbance measured at 725 nm using a UV-Vis spectrophotometer. Results were expressed as milligrams per liter of sample. Total phenolic content was determined using the Folin-Ciocalteu procedure with gallic acid standards at 10, 20, 30, 40, and 50 mg/L; absorbance was measured at 735 nm and results were expressed as milligrams of gallic acid equivalents per 100 g of sample (mg GAE/100 g). The Folin-Ciocalteu assay is a widely used colorimetric approach for estimating total reducing phenolic substances in food matrices.[16]

Estimated Nutrient Composition

The nutrient composition of each formulation was estimated from the quantities of ingredients using NutriSurvey 2007. These values were calculation-based estimates rather than laboratory measurements. The original formulation output used a 500-g serving basis.

Statistical Analysis

Data were analyzed using SPSS version 18.0. Mean sensory scores and laboratory values were compared using one-way analysis of variance. When the overall test was significant, Duncan's multiple range test was used for pairwise treatment comparisons. Statistical significance was defined as $p<0.05$. Values sharing the same superscript letter were interpreted as not significantly different.

Result and Discussion

Sensory Characteristics

Table 2. Sensory acceptance scores of nipah fruit pudding

Treatment	Color	Aroma	Texture	Taste
R1 (10%)	3.90^{a}	3.88^{a}	3.88^{a}	3.42^{a}
R2 (20%)	4.10^{a}	3.80^{a}	4.41^{b}	3.73^{a}
R3 (30%)	3.88^{a}	3.75^{a}	3.96^{a}	3.70^{a}
p-value	0.447	0.700	0.007	0.282

Values are mean hedonic scores. Different superscript letters within a column indicate significant differences according to Duncan's multiple range test ($p<0.05$).

Nipah fruit substitution significantly affected texture but not color, aroma, or taste. The 20% formulation achieved the highest scores for color, texture, and taste, while the 10% formulation had the highest aroma score. The absence of significant color differences is plausible because young nipah pulp is pale and translucent; in a milk-based matrix, the white appearance of milk proteins may dominate the visual profile. The mild fruit aroma and the identical amount of sweetener across formulations may likewise have limited detectable differences in aroma and sweetness.

Texture was the only sensory attribute that differed significantly. R2 received a higher texture score than both R1 and R3. Increasing nipah solids while reducing water can strengthen the gel by increasing dispersed solids and water-binding components. Nipah fruit has been reported to contain substantial fiber, and higher fiber content may contribute to firmness through water retention and matrix reinforcement.[10] However, excessive fruit solids may also produce a denser or less smooth texture, which could explain why acceptance did not continue to increase at 30%. Comparable gelled-fruit studies have shown that hydrocolloid concentration and fruit incorporation can materially change texture and consumer liking.[13,14]

Total Flavonoid and Phenolic Contents

Table 3. Total flavonoid and phenolic contents of nipah fruit pudding

Treatment	Flavonoids (mg/L)	Phenolics (mg GAE/100 g)
R1 (10%)	6.37^{a}	34.09^{a}
R2 (20%)	8.59^{b}	57.39^{b}
R3 (30%)	9.99^{c}	80.25^{c}
p-value	0.002	<0.001

Different superscript letters within a column indicate significant differences according to Duncan's multiple range test ($p<0.05$).

Both total flavonoid and total phenolic contents increased progressively with nipah fruit substitution, and all three formulations differed significantly. R3 contained approximately 57% more flavonoids and 135% more phenolics than R1. This dose-related pattern supports the interpretation that nipah fruit pulp was the principal contributor of the measured compounds. Previous analysis of nipah fruit extract similarly reported detectable flavonoid and phenolic fractions.[9]

The higher measured content is relevant to product development because flavonoids and phenolic compounds can contribute antioxidant and enzyme-modulating activities in experimental systems.[4-6] However, spectrophotometric total-content assays are nonspecific and do not identify individual compounds, their stability after processing, or their bioavailability. Heating, oxygen exposure, pH, and interactions with milk proteins may alter extractability and biological activity.[6,11] Thus, the present values demonstrate compositional differences among formulations but do not establish antidiabetic efficacy.

Estimated Nutrient Composition

Table 4. Estimated nutrient composition per 500-g portion

Nutrient	R1	R2	R3
Energy (kcal)	150.3	179.4	208.4
Protein (g)	10.0	11.5	12.9
Fat (g)	4.3	4.7	5.1
Carbohydrate (g)	40.5	68.7	96.9
Total sugar (g)	15	29	42
Dietary fiber (g)	1.3	2.5	3.8
Vitamin C (mg)	30.25	60.35	90.25

Values were estimated using NutriSurvey 2007 from formulation ingredients and were not verified by proximate laboratory analysis.

The calculated nutrient profile increased with the amount of nipah fruit, particularly for carbohydrate, total sugar, fiber, and vitamin C. Although higher dietary fiber intake is generally associated with improved glycemic outcomes in people with diabetes, the clinical effect depends on fiber type, dose, food matrix, portion size, and the accompanying available carbohydrate.[12,17] The estimated 500-g portion is larger than a typical snack serving, and the increase in carbohydrate and total sugar at higher substitution levels requires careful portion standardization before the product is positioned for people with diabetes.

Formulation Implications and Study Limitations

The findings show a practical trade-off between sensory acceptance and bioactive-compound concentration. R2 provided the strongest overall sensory performance, whereas R3 maximized total flavonoid and phenolic contents. For product optimization, 20% substitution may be the most suitable starting formulation, followed by targeted adjustment of serving size, sweetness, and texture. Alternatively, 30% substitution could be reformulated to improve texture while retaining higher bioactive content.

Several limitations should be considered. First, the design did not include a 0% nipah control, so the absolute contribution of nipah relative to conventional pudding could not be quantified. Second, the panel consisted of 25 moderately trained panelists from a single setting and was not representative of consumers. Third, the chemical assays measured total classes of compounds rather than individual phytochemicals, antioxidant activity, bioaccessibility, or in vivo effects. Fourth, nutrient values were estimated using software instead of laboratory proximate analysis. Finally, no postprandial glucose, insulin, safety, shelf-life, or clinical outcomes were assessed. These limitations preclude recommending the pudding as a therapeutic snack for diabetes.

Conclusion

Nipah fruit substitution increased the total flavonoid and phenolic contents of pudding while maintaining generally acceptable sensory properties. The 20% formulation achieved the best sensory profile, especially for texture, whereas the 30% formulation contained the highest measured bioactive compounds. Nipah fruit therefore shows potential as a locally sourced ingredient for functional food development. Before health claims or recommendations for people with diabetes are made, future studies should include a control formulation, representative consumer testing, laboratory nutrient and phytochemical characterization, shelf-life assessment, standardized portions, and controlled evaluation of postprandial glycemic responses.

Acknowledgment

The authors thank the Department of Nutrition, Poltekkes Kemenkes Aceh, the staff of the Food and Agricultural Product Analysis Laboratory at Universitas Syiah Kuala, and all panelists who participated in the sensory evaluation.

Authors' Contributions

SM: Conceptualization, methodology, investigation, data collection, laboratory coordination, formal analysis, and original draft preparation. AH: Supervision, methodology validation, interpretation, and critical manuscript revision. YF: Supervision, laboratory-method validation, interpretation, and manuscript review. All authors approved the final manuscript.

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