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Development of dim sum enriched with Jamaican cherry (*Muntingia calabura* L.) and cutleaf groundcherry (*Physalis angulata* L.) as a functional food for type 2 diabetes mellitus

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ABSTRACT
Background: Type 2 Diabetes Mellitus is a metabolic disorder with UV increasing prevalence and is closely associated with unhealthy dietary patterns. Functional foods containing bioactive compounds have gained attention as dietary alternatives for diabetes management. Jamaican cherry leaves (*Muntingia calabura* L.) and cutleaf groundcherry fruit (*Physalis angulata* L.) contain flavonoids and other bioactive compounds reported to possess antioxidant activity and potential antidiabetic properties. **Methods:** This experimental study used a Completely Randomized Design with three dim sum formulations containing different proportions of Jamaican cherry leaves and cutleaf groundcherry fruit: F1 (70:30), F2 (50:50), and F3 (30:70). Sensory evaluation was conducted with 20 untrained panelists using a five-point hedonic scale. Data were analyzed using the Kruskal–Wallis and Mann–Whitney tests. Nutrient content was calculated using the Indonesian Food Composition Table, whereas flavonoid content was estimated from published literature. The Exponential Comparison Method was used to determine the optimal formulation. **Findings:** All formulations were generally accepted, with sensory scores ranging from moderately liked to liked. No significant differences were observed in color, aroma, taste, or texture ($p > 0.05$), whereas aftertaste differed significantly ($p < 0.05$). Formulation F2 was selected as the optimal formulation, containing 248.59 kcal energy, 6.45% protein, 4.70% fat, 33.42% carbohydrates, 4.25% dietary fiber, and a literature-based estimated flavonoid content of 126.03 mg QE/100 g. **Conclusion:** The F2 formulation demonstrated favorable sensory acceptability and nutritional characteristics, indicating its potential as a functional snack for dietary management of Type 2 Diabetes Mellitus. However, further laboratory analyses and biological or clinical studies are required to validate its functional properties. **Novelty/Originality:** This study developed a dim sum formulation enriched with Jamaican cherry leaves and cutleaf groundcherry fruit and evaluated its sensory acceptability, nutritional composition, and estimated flavonoid content, providing preliminary evidence for developing functional foods for dietary management of Type 2 Diabetes Mellitus.

KEYWORDS: cutleaf groundcherry fruit; dim sum; flavonoids; Jamaican cherry leaves; type 2 diabetes mellitus

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1. Introduction

Diabetes Mellitus Type 2 (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from insulin resistance accompanied by impaired insulin secretion (Indonesian Endocrinology Association, 2024). It is one of the leading public health challenges worldwide because of its rapidly increasing prevalence and substantial burden on healthcare systems. According to the International Diabetes Federation, approximately 537 million adults aged 20–79 years were living with diabetes in 2021, and this number is projected to increase considerably in the coming decades (International Diabetes Federation, 2021). Globally, Type 2 Diabetes Mellitus accounts for approximately 90% of all diabetes cases (Yang et al., 2025).

In Indonesia, the prevalence of T2DM has also shown a concerning upward trend. According to the 2023 Indonesian Health Survey, the prevalence of diabetes increased to 11.7%, compared with 10.9% reported in the 2018 Basic Health Research (Ministry of Health of the Republic of Indonesia, 2023). Furthermore, Indonesia ranks fifth among countries with the highest number of people living with diabetes, with approximately 19.5 million cases reported in 2021 (International Diabetes Federation, 2021). Obesity remains one of the major contributing factors to this increasing burden, as individuals with obesity have a substantially higher risk of developing T2DM than those with normal body weight (Chamarti et al., 2025).

The increasing prevalence of T2DM is closely associated with unhealthy lifestyles, particularly excessive consumption of sugar- and fat-rich foods, inadequate dietary fiber intake, and insufficient physical activity (Azhar et al., 2022). These factors contribute to insulin resistance and chronic hyperglycemia, which may eventually lead to serious complications including cardiovascular disease, nephropathy, retinopathy, neuropathy, and other metabolic disorders (Azhar et al., 2022; Harsa & Mulyasari, 2023). Consequently, dietary management has become one of the primary approaches for preventing disease progression and reducing diabetes-related complications. In recent years, functional foods enriched with bioactive compounds have attracted considerable attention as complementary dietary strategies because they may improve glycemic regulation while simultaneously providing additional nutritional benefits (Ansari et al., 2023).

Among the bioactive compounds found in functional foods, flavonoids have received considerable attention because of their antioxidant, anti-inflammatory, and potential antihyperglycemic properties (Pratiwi & Santika, 2023). Previous studies have demonstrated that flavonoids may improve glucose homeostasis through multiple mechanisms, including inhibition of α-glucosidase and α-amylase activities, enhancement of insulin sensitivity, reduction of oxidative stress, protection of pancreatic β-cells, activation of AMP-activated protein kinase (AMPK), promotion of glucose transporter type 4 (GLUT4) translocation, and suppression of inflammatory signaling pathways (Andhiarto et al., 2022; Yi et al., 2023; Lam et al., 2024). These biological activities suggest that flavonoids may have potential roles in supporting dietary management of Type 2 Diabetes Mellitus.

In addition to flavonoids, dietary fiber is another important component of functional foods intended for individuals with T2DM. Soluble dietary fiber delays gastric emptying, reduces intestinal glucose absorption, and attenuates postprandial blood glucose excursions. Furthermore, fermentation of dietary fiber by the gut microbiota produces short-chain fatty acids (SCFAs), which stimulate the secretion of glucagon-like peptide-1 (GLP-1) and peptide YY (PYY), thereby improving insulin secretion and insulin sensitivity (Giuntini et al., 2022; Pham et al., 2023). Therefore, functional foods containing both flavonoids and dietary fiber may provide complementary nutritional benefits that support glycemic regulation as part of dietary management for individuals with Type 2 Diabetes Mellitus.

Jamaican cherry leaves (*Muntingia calabura* L.) are an underutilized tropical plant that has attracted increasing scientific interest because of its rich phytochemical composition and potential health benefits. Previous phytochemical studies have reported that Jamaican

cherry leaves contain flavonoids, phenolic compounds, tannins, saponins, and alkaloids, which contribute to their antioxidant, anti-inflammatory, and antihyperglycemic activities (Pratiwi & Santika, 2023). The flavonoid content of Jamaican cherry leaves has been reported to reach 46.51 mg QE/g extract, indicating their potential as a rich source of bioactive compounds for functional food development (Dimas et al., 2022). Previous experimental studies have suggested that Jamaican cherry leaf extracts may influence glucose metabolism through inhibition of carbohydrate-digesting enzymes, decreasing oxidative stress, and improving pancreatic β-cell function (Andhiarto et al., 2022; Febriyanti et al., 2025). In addition to these biological activities, Jamaican cherry leaves are widely available in Indonesia, inexpensive, and have not been extensively utilized as food ingredients, making them promising candidates for the development of functional foods.

Cutleaf groundcherry fruit (*Physalis angulata* L.) is another indigenous plant recognized for its nutritional value and bioactive compounds. The fruit contains flavonoids, polyphenols, carotenoids, vitamin C, and other antioxidant constituents that have been associated with antioxidant and anti-inflammatory properties, with potential relevance to glucose metabolism. In addition, cutleaf groundcherry fruit has been reported to contain flavonoids with an average concentration of 15.65 mg QE/g, further supporting its potential application as a functional food ingredient (Khoerunnisa, 2024). Several studies have reported that bioactive compounds present in cutleaf groundcherry fruit may improve glucose metabolism by reducing oxidative stress and modulating insulin signaling pathways (Mishra et al., 2024). Furthermore, the fruit possesses a relatively mild flavor and pleasant aroma compared with many medicinal plants, making it more suitable for incorporation into food products without substantially reducing sensory acceptability. The combination of Jamaican cherry leaves and cutleaf groundcherry fruit may provide complementary phytochemical and nutritional properties, potentially enhancing the functional value of the product while improving sensory acceptability through the relatively mild flavor of cutleaf groundcherry fruit.

Incorporating bioactive plant ingredients into familiar ready-to-eat foods has emerged as a promising strategy to improve consumer acceptance while providing additional functional benefits. Dim sum was selected as the food matrix because it is a popular ready-to-eat food that can accommodate plant-based functional ingredients while maintaining consumer familiarity, convenience, and acceptable sensory characteristics.

Recent studies have demonstrated the potential of *Muntingia calabura* L. and *Physalis angulata* L. as functional food ingredients. Jamaican cherry leaves have been incorporated into herbal beverages, teas, and bakery products because of their high flavonoid content and antioxidant potential (Pratiwi & Santika, 2023), whereas cutleaf groundcherry has been utilized in beverages, jams, and herbal tea products because of its nutritional quality and functional properties (Khoerunnisa, 2024). For example, Yantoyo et al. (2024) developed a herbal tea formulated from Jamaican cherry leaves and mint leaves, while Widiyana et al. (2021) developed a herbal tea from cutleaf groundcherry leaves supplemented with ginger powder and evaluated its flavonoid content, antioxidant activity, and sensory characteristics. However, these studies investigated each plant separately and mainly focused on beverage products. Evidence regarding the combined incorporation of Jamaican cherry leaves and cutleaf groundcherry fruit into a ready-to-eat functional food product remains limited. Moreover, few studies have simultaneously evaluated sensory acceptability, nutritional composition, estimated flavonoid content, nutrient contribution for individuals with Type 2 Diabetes Mellitus, compliance with Indonesian nutrition claim regulations, and economic feasibility. Addressing these gaps is important because successful functional food development requires not only the incorporation of bioactive compounds but also acceptable sensory quality, adequate nutritional composition, regulatory compliance, and economic feasibility. Therefore, the present study developed functional dim sum enriched with Jamaican cherry leaves and cutleaf groundcherry fruit to address these research gaps by comprehensively evaluating sensory acceptability, nutritional composition, literature-based estimated flavonoid content, nutrient claims, and production cost.

Flavonoid content in plant-based functional foods is commonly determined using analytical techniques such as spectrophotometry or High-Performance Liquid Chromatography (HPLC), which provide direct quantification of bioactive compounds. For example, Alfiraza et al. (2024) quantified total flavonoid content in Jamaican cherry leaf extract using Ultraviolet visible (UV–Vis) spectrophotometry with quercetin as the standard reference. However, literature-based estimation may be used as a preliminary approach during early product development when laboratory analysis is not feasible, although the estimated values require subsequent validation through analytical methods (Zhang et al., 2024).

Unlike previous studies that primarily focused on individual plant materials or beverage products, the present study developed a ready-to-eat functional dim sum incorporating both Jamaican cherry leaves and cutleaf groundcherry fruit. In addition, this study integrates sensory evaluation, nutritional composition analysis, literature-based estimation of flavonoid content, formulation optimization using the Exponential Comparison Method, nutrient contribution assessment, nutrient claim evaluation according to Indonesian food regulations, and economic feasibility analysis. This comprehensive approach provides preliminary evidence supporting the development of locally sourced functional foods for dietary management of Type 2 Diabetes Mellitus.

Accordingly, this study aimed to develop functional dim sum enriched with Jamaican cherry leaves (*Muntingia calabura* L.) and cutleaf groundcherry fruit (*Physalis angulata* L.) and to evaluate the sensory acceptability, nutritional composition, and literature-based estimated flavonoid content. Furthermore, the optimal formulation was determined using the Exponential Comparison Method, while its nutrient contribution, nutrient claims according to Indonesian food regulations, and economic feasibility were also assessed.

2. Methods

2.1 Design, setting, and time

This experimental study used a Completely Randomized Design (CRD) with three treatments. The proportions of Jamaican cherry leaves (*Muntingia calabura L.*) and cutleaf groundcherry fruit (*Physalis angulata L.*) were F1 (70%:30%), F2 (50%:50%), and F3 (30%:70%). The study involved product conceptualization, preparation of Jamaican cherry leaf extract, formulation trials, product production, hedonic evaluation, and selection of the best formulation. Product development and sensory evaluation were conducted at the Food Technology Laboratory, Poltekkes Kemenkes Semarang, Indonesia. The study was conducted from February to April 2026.

2.2 Materials and equipment

The materials used in the development of dim sum enriched with Jamaican cherry leaves (*Muntingia calabura L.*) and cutleaf groundcherry fruit (*Physalis angulata L.*) included Jamaican cherry leaf extract, rice flour, tapioca flour, modified cassava flour (mocaf), chicken meat, carrots, dried wood ear mushrooms, chicken eggs, dried chili, tomatoes, Greek yogurt, and cutleaf groundcherry fruit. The equipment used for product preparation consisted of knives, cutting boards, measuring cups, a frying pan, a steamer, a food chopper, digital scales, and spatulas. Three formulations were developed by varying the proportions of Jamaican cherry leaf extract and cutleaf groundcherry fruit, as presented in Table 1.

Table 1. Formulation of dim sum enriched with Jamaican cherry leaves and cutleaf groundcherry fruit

Ingredients	F1 (g) 70%:30%	F2 (g) 50%:50%	F3 (g) 30%:70%
Dim sum Wrapper			

Ingredients	F1 (g) 70%:30%	F2 (g) 50%:50%	F3 (g) 30%:70%
Jamaican cherry leaf extract	70	70	70
Rice flour	100	100	100
Tapioca flour	25	25	25
Dim sum Filling			
Cutleaf groundcherry fruit	10	15	20
Jamaican cherry leaves	20	15	10
Chicken meat	100	100	100
Carrot	20	20	20
Dried wood ear mushroom	30	30	30
Modified cassava flour (Mocaf)	30	30	30
Chicken egg	50	50	50
Dim sum Sauce			
Tomato	25	25	25
Dried chili	5	5	5
Greek yogurt	20	20	20
Cutleaf groundcherry fruit	20	20	20
Total	525	525	525

2.3 Product preparation

The materials used in this study included Jamaican cherry leaves, cutleaf groundcherry fruits, rice flour, tapioca flour, mocaf flour, chicken meat, eggs, garlic, salt, pepper, tomatoes, shallots, chili powder, vegetable oil, yogurt, and other supporting ingredients according to the formulation. Standard food preparation equipment, including a stove, steamer, blender, food chopper, analytical balance, and common kitchen utensils, was used throughout the study.

Jamaican cherry leaf extract was prepared using a hot-water extraction (decoction) method by heating fresh leaves with distilled water at a ratio of 1:10 (w/v) at approximately 90 °C for 15–30 minutes, followed by cooling and filtration. The prepared Jamaican cherry leaf extract was used for the dim sum wrapper, whereas fresh Jamaican cherry leaves were incorporated into the filling according to each formulation. Three dim sum formulations were prepared with different proportions of Jamaican cherry leaves and cutleaf groundcherry fruit (F1 = 70:30, F2 = 50:50, and F3 = 30:70). Dim sum wrappers were produced from wheat and tapioca flour, while the filling consisted of chicken meat, Jamaican cherry leaves, cutleaf groundcherry fruit, mocaf flour, eggs, garlic, salt, and pepper. A complementary sauce was prepared from cutleaf groundcherry fruit, tomatoes, garlic, shallots, chili powder, vegetable oil, water, and yogurt.

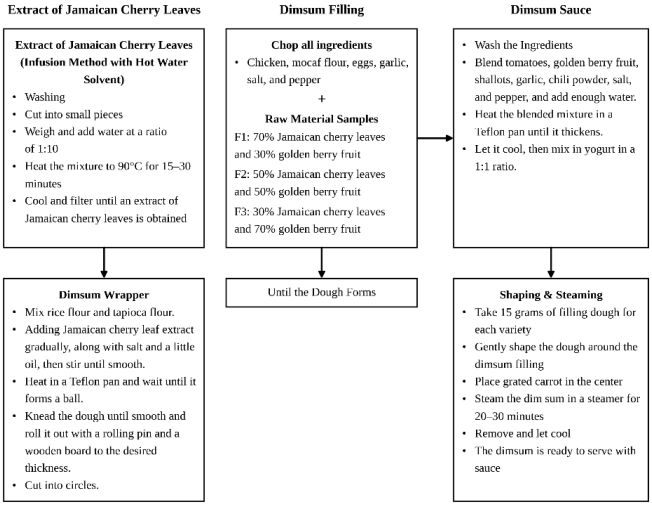

Fig. 1. The dim sum production process

Approximately 15 g of filling was wrapped in each dim sum wrapper, manually shaped, and steamed at approximately 100 °C for 20–30 minutes until fully cooked. After cooling to room temperature, the samples were subjected to sensory evaluation, nutritional composition analysis, and flavonoid content estimation. The detailed production procedure is presented in Figure 1.

2.4 Organoleptic test

The sensory acceptability of the developed dim sum products was evaluated using a hedonic test involving 20 untrained panelists representing potential consumers. Three formulations (F1, F2, and F3), differing in the proportions of Jamaican cherry leaves and cutleaf groundcherry fruit, were evaluated after being prepared under identical processing conditions. Samples were served in equal portions, labeled with random three-digit codes, and presented in randomized order to minimize bias and order effects.

The evaluated sensory attributes included color, aroma, taste, texture, and aftertaste. Each attribute was assessed using a five-point hedonic scale: 1 = dislike very much, 2 = dislike, 3 = moderately like, 4 = like, and 5 = like very much. Panelists completed a hedonic questionnaire independently, and drinking water was provided between samples to minimize carry-over effects.

The hedonic scores obtained for each attribute were recorded and analyzed to compare the sensory acceptability of the three formulations. The results were expressed as mean hedonic scores and were used as one of the criteria for determining the optimal formulation.

2.5 Nutrient content analysis

Nutrient content analysis was conducted to determine the energy and nutrient composition of the dim sum formulations enriched with Jamaican cherry leaves and cutleaf groundcherry fruit. The analyzed components included energy, protein, fat, carbohydrates, and dietary fiber. Nutrient values were estimated using the Indonesian Food Composition Table/*Tabel Komposisi Pangan Indonesia* (TKPI) 2020 based on the quantity of each ingredient in the formulation. Data processing was performed using Microsoft Excel. The results were expressed per 100 g of product and compared with the nutritional requirements for foods intended for special dietary use for individuals with Diabetes Mellitus as stipulated in the Indonesian Food and Drug Authority Regulation or *Badan Pengawas Obat dan Makanan Republik Indonesia* (BPOM RI) No. 24 of 2019.

2.6 Estimated flavonoid content

Flavonoid content was estimated using a literature-based calculation approach rather than direct laboratory analysis. Reported flavonoid values were obtained from peer-reviewed scientific literature and expressed as milligrams of quercetin equivalents (mg QE)/g of raw material. The estimated flavonoid content of each dim sum formulation was calculated based on the flavonoid content of each functional ingredient and its proportion in the formulation, and expressed as mg QE/100 g of product. These estimated values were used solely for comparative purposes among formulations and should not be interpreted as laboratory-determined flavonoid concentrations.

2.7 Data analysis

Hedonic test data were analyzed using Microsoft Excel to obtain descriptive statistics, including mean and standard deviation for each sensory attribute. Data normality was assessed using the Shapiro–Wilk test. Since the data were not normally distributed ($p < 0.05$), differences among formulations were analyzed using the Kruskal–Wallis test with a significance level of 5% ($\alpha = 0.05$). When significant differences were observed, pairwise

comparisons were performed using the Mann–Whitney U test. All statistical analyses were conducted using IBM Statistical Package for the Social Sciences (SPSS) Statistics.

2.8 Selection of the best formulation

The best formulation was determined based on sensory acceptability and nutritional characteristics relevant to individuals with Type 2 Diabetes Mellitus. The evaluated parameters included color, aroma, texture, taste, aftertaste, energy, carbohydrate, fat, protein, dietary fiber, and estimated flavonoid content. The Exponential Comparison Method (ECM) was used to rank the formulations. The weighting of each parameter was determined according to its relative importance in selecting the optimal functional food formulation for individuals with Type 2 Diabetes Mellitus. The formulation with the highest overall score was selected as the best formulation.

2.9 Product contribution to nutrition facts reference (NFR)

The contribution of the selected dim sum formulation (F2) to daily nutrient requirements was evaluated using hypothetical adult profiles with Type 2 Diabetes Mellitus. Reference body weight and height for males and females aged 19–29 years and 30–49 years were obtained from the Indonesian Recommended Dietary Allowance (RDA) issued by the Ministry of Health of the Republic of Indonesia (Ministry of Health of the Republic of Indonesia, 2019). Daily energy requirements were estimated according to the 2021 Indonesian guideline for the management and prevention of Type 2 Diabetes Mellitus, assuming a light physical activity level (Indonesian Society of Endocrinology, 2021).

Nutrient content was expressed per 100 g of product and used to calculate its contribution to daily nutrient requirements. Nutrition claims were evaluated according to BPOM Regulation No. 9 of 2016 and BPOM Regulation No. 1 of 2022 (*Badan Pengawas Obat dan Makanan Republik Indonesia* (BPOM), 2016, 2022). Dietary fiber was selected as the primary claim parameter, with products containing ≥ 3 g/100 g classified as a source of dietary fiber and those containing ≥ 6 g/100 g classified as high in dietary fiber.

3. Results and Discussion

3.1 Organoleptic test

The hedonic evaluation was conducted to assess panelists' acceptance of the dim sum formulations based on color, aroma, taste, texture, and aftertaste using a five-point hedonic scale. Overall, all formulations achieved mean scores ranging from moderately liked to liked, indicating acceptable sensory characteristics.

Table 2. Hedonic test results of dim sum

Parameters	Average ± SD			p-value
	F1	F2	F3	
Color	3.60 ± 0.75[a]	3.60 ± 0.75[a]	3.65 ± 0.81[a]	0.974
Aroma	3.50 ± 0.94[a]	3.75 ± 0.71[a]	3.70 ± 0.80[a]	0.780
Taste	3.00 ± 1.02[a]	3.55 ± 0.68[a]	3.45 ± 0.94[a]	0.113
Texture	3.60 ± 0.50[a]	3.80 ± 0.61[a]	3.60 ± 0.88[a]	0.681
Aftertaste	3.20 ± 0.83[a]	3.80 ± 0.69[b]	3.75 ± 0.78[b]	0.027*

Note: [a,b:] Different letters on the same row indicate a statistically significant difference ($p < 0.05$).

As presented in Table 2, no significant differences were observed among formulations in terms of color ($H = 0.053$, $p = 0.974$), aroma ($H = 0.496$, $p = 0.780$), taste ($H = 4.361$, $p = 0.113$), and texture ($H = 0.769$, $p = 0.681$) ($p > 0.05$). In contrast, aftertaste showed a significant difference among formulations ($H = 7.216$, $p = 0.027$, $\varepsilon^2 = 0.091$), indicating a moderate effect size. Further analysis using the Mann–Whitney test revealed that

formulations F2 and F3 had significantly higher aftertaste scores than F1. Overall, F2 demonstrated the highest level of sensory acceptance among the tested formulations.

Consumer acceptance is an important consideration in the development of functional foods because it influences the likelihood of sustained consumption. In addition to providing health-promoting bioactive compounds, functional foods must possess acceptable sensory characteristics to ensure consumer preference and product utilization. In the present study, all dim sum formulations achieved mean hedonic scores ranging from moderately liked to liked, indicating that the incorporation of Jamaican cherry leaves and cutleaf groundcherry fruit was generally acceptable to the panelists.

Regarding color, formulation F3 obtained the highest mean score, although the difference was not statistically significant. This result suggests that increasing the proportion of cutleaf groundcherry fruit did not negatively affect the visual appearance of the product. Color is one of the first quality attributes perceived by consumers and plays an important role in determining food acceptance. During steaming, chlorophyll pigments present in plant-based ingredients may undergo degradation due to heat exposure, leading to the formation of pheophytin and a reduction in the intensity of the green color (Hirono et al., 2024). Nevertheless, the relatively similar color scores among formulations indicate that the different proportions of Jamaican cherry leaves and cutleaf groundcherry fruit did not substantially alter the visual characteristics of the dim sum.

Although aroma, taste, and texture did not differ significantly among formulations, F2 tended to receive higher preference scores than F1 and F3. This finding may be attributed to the balanced proportion of Jamaican cherry leaves and cutleaf groundcherry fruit used in F2. Jamaican cherry leaves contain flavonoids, tannins, and other phenolic compounds that contribute to their functional properties but may also impart bitter and astringent sensory characteristics when incorporated at high concentrations (Pratiwi & Santika, 2023). Conversely, cutleaf groundcherry fruit possesses a milder flavor profile and contains bioactive compounds that can complement the sensory properties of food products (Khoerunnisa, 2024). Therefore, the balanced formulation in F2 may have produced a more harmonious sensory profile, resulting in higher consumer acceptance.

A significant difference was observed in the aftertaste parameter, with F2 achieving the highest preference score. The lower aftertaste acceptance of F1 may be associated with its higher proportion of Jamaican cherry leaves, which could intensify the lingering bitter or astringent sensation caused by tannins and phenolic compounds. Similar observations have been reported in studies showing that higher concentrations of phenolic compounds may reduce sensory acceptability despite their beneficial biological activities (Pratiwi & Santika, 2023). The addition of cutleaf groundcherry fruit in a balanced proportion appears to reduce these undesirable sensory effects while maintaining the functional potential of the product.

The present findings suggest that formulation F2 provided the most favorable sensory profile among the tested formulations. The balanced combination of Jamaican cherry leaves and cutleaf groundcherry fruit improved overall acceptability across sensory attributes, particularly aftertaste, while maintaining the potential functional properties associated with their bioactive compounds.

3.2 Nutrition content

The nutritional composition of the developed dim sum formulations was analyzed to evaluate the effect of varying proportions of Jamaican cherry leaves and cutleaf groundcherry fruit on the nutrient content. The results are presented in Table 3.

As shown in Table 3, only slight variations were observed in the nutritional composition among the three formulations. Energy content ranged from 245.44 to 251.73 kcal per 100 g, with F1 showing the highest value and F3 the lowest. Protein content remained relatively stable across formulations (6.43–6.46%), while fat content showed minimal variation (4.69–4.71%). Similarly, carbohydrate content ranged narrowly between 33.42% and 33.48%. These findings indicate that varying the proportions of Jamaican

cherry leaves and cutleaf groundcherry fruit had limited influence on the overall macronutrient composition of the dim sum.

Table 3. Nutritional composition of dim sum per 100 g

Parameters	F1	F2	F3	PKMK Standard
Energy (kcal)	251.73	248.59	245.44	-
Protein (%)	6.43	6.45	6.46	2.5-5*
Fat (%)	4.71	4.70	4.69	2.22-2.78
Carbohydrate (%)	33.47	33.42	33.48	11.25-16.25*
Dietary Fiber (%)	4.67	4.65	4.63	1-1.75*

Note: *Indicates compliance with the nutritional requirements of the Indonesian Ministry of Health Regulation (Processed Foods for Special Medical Purposes No. 24 of 2019).

Dietary fiber content ranged from 4.63% to 4.67%, with F1 exhibiting the highest value. Although the differences were not substantial, dietary fiber represents a key functional component in food products intended for individuals with type 2 diabetes mellitus. Compared with the Indonesian Ministry of Health Regulation (*Pangan Olahan untuk Keperluan Medis Khusus* (PKMK) No. 24 of 2019), all formulations met the recommended criteria for protein, carbohydrate, and dietary fiber content, indicating their suitability as food products with improved nutritional profiles.

From a functional perspective, the presence of dietary fiber in all formulations may contribute to glycemic control by slowing gastric emptying, reducing glucose absorption in the intestine, and improving postprandial blood glucose response (Rahmadani, 2025). In addition, the relatively moderate fat content suggests a balanced energy density, which is beneficial in supporting dietary management for individuals with type 2 diabetes mellitus.

Collectively, variations in ingredient proportions had minimal impact on macronutrient composition, while dietary fiber content highlights the functional potential of all formulations. These findings suggest that the developed dim sum has the potential to serve as a health-oriented snack alternative with relatively stable macronutrient profiles across formulations.

The relatively similar nutritional profiles observed across the formulations indicate that replacing Jamaican cherry leaves with cutleaf groundcherry fruit did not substantially alter the macronutrient composition of the product. This finding is expected because both ingredients were incorporated in relatively small amounts, while the principal contributors to energy and macronutrients, namely chicken meat, wheat flour, tapioca flour, mocaf flour, and eggs, remained constant across formulations. Therefore, changes in the proportions of Jamaican cherry leaves and cutleaf groundcherry fruit mainly affected the functional components of the product, particularly dietary fiber and flavonoid content, rather than its overall nutritional composition. This characteristic is advantageous for functional food development, as improvements in bioactive compounds can be achieved without markedly changing the nutritional profile or energy contribution of the product.

3.3 Estimated flavonoid content

The estimated flavonoid content of the developed dim sum formulations was calculated based on previously published analytical data to estimate the contribution of Jamaican cherry leaves and cutleaf groundcherry fruit to the functional properties of the product. The results are presented in Table 4.

Table 4. Estimated flavonoid content (mg QE/100 g)

Formula	Total Estimated Flavonoid Content (mg QE/100g)
F1	136.25
F2	126.03
F3	115.59

As presented in Table 4, the estimated flavonoid content varied among the formulations, ranging from 115.59 to 136.25 mg QE/100 g. Formulation F1 showed the highest estimated flavonoid content (136.25 mg QE/100 g), followed by F2 (126.03 mg QE/100 g) and F3 (115.59 mg QE/100 g). These findings indicate a gradual decrease in flavonoid content with the increasing proportion of cutleaf groundcherry fruit, suggesting that Jamaican cherry leaves contributed more significantly to the total flavonoid content of the product.

Based on published analytical data, the higher estimated flavonoid content observed in F1 was primarily associated with the greater proportion of Jamaican cherry leaves incorporated into the formulation. Accordingly, the estimated flavonoid content decreased from F1 to F3 as the proportion of Jamaican cherry leaves was reduced and replaced with cutleaf groundcherry fruit. Although cutleaf groundcherry fruit also contains various bioactive compounds, published studies suggest that its flavonoid content is generally lower than that of Jamaican cherry leaves. Therefore, the estimated values presented in this study reflect the expected contribution of each ingredient based on previously published analytical data rather than direct laboratory measurements of the developed formulations.

Flavonoids are well-documented for their antioxidant activity, primarily through their ability to scavenge reactive oxygen species (ROS) and reduce oxidative stress. In addition, flavonoids have been reported to improve insulin sensitivity and inhibit carbohydrate-digesting enzymes such as α-glucosidase and α-amylase, thereby slowing glucose absorption in the intestine. These mechanisms have been demonstrated in previous experimental studies and may contribute to glycemic regulation in individuals with Type 2 Diabetes Mellitus (Febriyanti et al., 2025). However, the present study did not directly determine flavonoid content through laboratory analysis, nor did it evaluate antioxidant activity, enzyme inhibition, glycemic response, or other biological effects. Therefore, these mechanisms are discussed solely to provide scientific context and should not be interpreted as evidence of the biological activity or antidiabetic efficacy of the developed product.

Dietary fiber and flavonoids may work synergistically to improve glycemic control through complementary mechanisms. Soluble dietary fiber slows gastric emptying and carbohydrate absorption by increasing the viscosity of the food bolus. In addition, the fermentation of dietary fiber by the gut microbiota produces short-chain fatty acids, which stimulate the secretion of glucagon-like peptide-1 (GLP-1) and peptide YY (PYY), hormones that help improve insulin secretion and sensitivity (Giuntini et al., 2022; Pham et al., 2023). Meanwhile, Flavonoids can simultaneously inhibit the activity of the enzymes α-glucosidase and α-amylase, thereby slowing the breakdown of starch and reducing the postprandial rise in blood sugar (Lam et al., 2024) . Previous studies have also shown that the interaction between dietary fiber and flavonoids within the food matrix may influence the bioaccessibility and bioavailability of flavonoids, thereby affecting their potential health benefits (Kamiloglu et al., 2021).

Taken together, the estimated flavonoid content indicates that all formulations may provide flavonoids derived from Jamaican cherry leaves and cutleaf groundcherry fruit, with F1 showing the highest estimated flavonoid value among the tested formulations. However, because these values were estimated from published literature rather than determined through laboratory analysis, the actual flavonoid content of the developed products remains to be confirmed. Furthermore, the antioxidant and antidiabetic properties of the formulations were not evaluated in this study. Therefore, laboratory validation of flavonoid content and further biological investigations are necessary before any conclusions regarding their functional efficacy can be drawn.

3.4 Best formulation

The optimal formulation was determined using the Exponential Comparison Method (ECM), which integrates sensory acceptability and nutritional characteristics through a weighted scoring system. The parameters included taste, aroma, color, texture, aftertaste, energy, fat, protein, carbohydrate, dietary fiber, and estimated flavonoid content. Dietary

fiber and total flavonoid content were assigned the highest weighting factors (20% each), followed by taste (15%) and protein content (10%). This weighting scheme was designed to prioritize both functional properties and consumer acceptability, which are important considerations in the development of a potential functional snack intended for individuals with Type 2 Diabetes Mellitus.

Table 5. Determination of the best formulation

Parameters	Weighting Factor (%)	Formula Score					
		F1		F2		F3	
		Rank	Score	Rank	Score	Rank	Score
Taste	15	3	0.45	1	0.05	2	0.30
Aroma	5	3	0.15	1	0.05	2	0.10
Color	5	2	0.10	1	0.05	3	0.15
Texture	5	3	0.15	1	0.05	2	0.10
Aftertaste	5	3	0.15	1	0.05	2	0.10
Energy	5	1	0.05	2	0.10	3	0.15
Fat	5	1	0.05	2	0.10	3	0.15
Protein	10	3	0.30	2	0.20	1	0.10
Carbohydrate	5	2	0.10	1	0.05	3	0.15
Dietary Fiber	20	1	0.20	2	0.40	3	0.60
Estimated Flavonoid Content	20	1	0.20	2	0.40	3	0.60
Total Score	100		1.9		1.6		2.5
Final Ranking		2		1		3	

As presented in Table 5, F2 obtained the lowest total ECM score (1.6) and was ranked first, followed by F1 with a score of 1.9 and F3 with a score of 2.5. In this assessment, a lower total score indicates a more favorable formulation because it reflects better overall performance across the weighted sensory and nutritional criteria. The results demonstrate that F2 provided the most balanced profile among the three formulations.

F2 ranked first in all sensory parameters, including taste, aroma, color, texture, and aftertaste. This finding indicates that F2 had the highest level of panelist acceptance and the most desirable sensory characteristics. Sensory acceptability is particularly important in functional food development because a product with high nutritional or bioactive value may have limited practical application if it is not preferred by consumers. The favorable sensory profile of F2 may indicate that the proportion of Jamaican cherry leaf and cutleaf groundcherry fruit enrichment was sufficient to provide functional value without producing an excessively strong herbal flavor, bitterness, or undesirable aftertaste.

In terms of nutritional composition, F2 showed intermediate rankings for energy, fat, protein, carbohydrate, dietary fiber, and estimated flavonoid content. Although it did not contain the highest dietary fiber and flavonoid levels, F2 still provided these functional components while maintaining superior sensory quality. Dietary fiber is relevant for type 2 diabetes mellitus management because it may contribute to improved satiety and a slower postprandial glucose response. Similarly, flavonoids may provide antioxidant activity and may help reduce oxidative stress associated with diabetes-related metabolic disturbances. Therefore, the presence of these components in F2 supports its potential as a functional snack product.

F1 showed the highest ranks for dietary fiber and estimated flavonoid content, indicating greater potential as a source of dietary fiber and flavonoid compounds based on the formulation design. However, the actual flavonoid content and biological activity of the developed product require laboratory validation. However, it ranked lower for taste, aroma, texture, and aftertaste. This suggests that the higher proportion of functional ingredients may have negatively influenced sensory characteristics, potentially resulting in a stronger herbal aroma, bitter taste, or more pronounced aftertaste. Meanwhile, F3 demonstrated relatively favorable nutritional characteristics, particularly for protein content, but did not show the same overall balance of sensory acceptance and nutritional quality as F2.

The ECM results indicate that F2 was the most favorable formulation because it provided the best balance between sensory acceptability, nutritional composition, and estimated flavonoid content among the tested formulations. These findings suggest that F2 has potential for further development as a functional dim sum product. However, its potential application for individuals with Type 2 Diabetes Mellitus should be interpreted with caution, as the flavonoid content was estimated from published literature and no laboratory, preclinical, or clinical evaluations were performed to confirm its biological activity or antidiabetic efficacy.

3.5 Contribution of nutrient content to the RDA of type 2 diabetes mellitus patients

The contribution of the selected dim sum formulation (F2) to daily nutrient requirements was evaluated using hypothetical adult profiles with Type 2 Diabetes Mellitus. Reference body weight and height for males and females aged 19–29 years and 30–49 years were obtained from the Indonesian Recommended Dietary Allowance (Ministry of Health of the Republic of Indonesia, 2019). These reference anthropometric values were subsequently used to estimate individual energy requirements according to the 2021 Indonesian Type 2 Diabetes Mellitus management guideline, assuming a light physical activity level (Indonesian Society of Endocrinology, 2021). The estimated energy requirement was then used as the basis for calculating daily macronutrient and dietary fiber requirements. Therefore, the percentage values presented in Table 6 represent the contribution of one serving of the product to estimated nutrient requirements for adults with Type 2 Diabetes Mellitus, rather than direct percentages of the general Recommended Dietary Allowance.

Table 6. Contribution of one serving of selected dim sum formulation (90 g/4 pieces)

Composition	Nutrient Content per Serving (90 g/4 pieces)	% adequacy level for age group 19-29 years		% adequacy level for age group 30-49 years	
RDA		M	F	M	F
Energy (kcal)	223.70	10.15	14.04	10.46	14.29
Protein (%)	5.80	7.02	9.71	7.23	9.88
Fat (%)	4.23	6.91	9.56	7.12	9.72
Carbohydrate (%)	30.07	9.10	12.59	9.37	12.80
Dietary Fiber (%)	4.18	11.29	13.06	11.61	13.93

As shown in table 6, one serving of the selected formulation, equivalent to 90 g or four pieces of dim sum, provided 223.70 kcal of energy, 5.80 g of protein, 4.23 g of fat, 30.07 g of carbohydrate, and 4.18 g of dietary fiber. The energy contribution ranged from 10.15% to 14.29% of the estimated daily energy requirements across the hypothetical adult groups. This range is consistent with the recommended contribution of snacks, which generally provide approximately 10–15% of total daily energy intake (Majid & Farida, 2024). Thus, one serving of the selected dim sum formulation may be considered appropriate as a snack portion for adults with Type 2 Diabetes Mellitus with light physical activity, provided that its intake is incorporated into the individual daily meal plan.

The protein contribution of one serving ranged from 7.02% to 9.88% of the estimated daily requirement. Meanwhile, fat and carbohydrate contributed 6.91–9.72% and 9.10–12.80%, respectively. These findings indicate that the selected dim sum formulation provides a moderate contribution to daily macronutrient intake and can be incorporated as an intermeal food without exceeding the expected energy contribution of a snack. Nevertheless, carbohydrate intake should remain distributed across main meals and snacks according to individual energy needs, nutritional status, medication use, and blood glucose control (American Diabetes Association, 2025).

Dietary fiber contributed 11.29–13.93% of the estimated daily requirement. This contribution is relevant because dietary fiber may help support postprandial glycemic

regulation by slowing gastric emptying and reducing the rate of glucose absorption (Giuntini et al., 2022). The fiber content also provides added value to the product because it contributes a meaningful proportion of daily fiber needs within one snack serving. Therefore, the selected formulation has potential to be developed as a functional snack alternative that supports the implementation of dietary management in adults with Type 2 Diabetes Mellitus.

Table 7. Nutrient claim assessment of selected dim sum formulation F2 based on nutrition facts reference per 100 g

Composition	Nutrient Content (100 g)	% Nutrition Facts Reference	Nutrient Claim
Energy (kcal)	248.59	11.56	–
Protein (%)	6.45	10.75	–
Fat (%)	4.70	7.01	–
Carbohydrate (%)	33.42	10.28	–
Dietary Fiber (%)	4.65	15.50	Source

Table 7 presents the results of the nutrient claim assessment based on the nutrient composition per 100 g of the product and the Nutrition Facts Reference criteria. The selected formulation contained 4.65 g of dietary fiber per 100 g, equivalent to 15.50% of the Nutrition Facts Reference. Based on BPOM Regulation No. 1 of 2022, a solid food product containing at least 3 g of dietary fiber per 100 g is eligible for a source of dietary fiber claim. Therefore, the selected dim sum formulation fulfills the requirements to be labeled as a source of dietary fiber.

Based on the nutrient contribution and nutrient claim assessment, the selected dim sum formulation has the potential to be developed as a functional snack alternative for adults with Type 2 Diabetes Mellitus with light physical activity. One serving provides an energy contribution within the expected range for a snack and contributes more than 10% of the estimated daily dietary fiber requirement. In addition, the product fulfills the criteria for a source of dietary fiber claim (*Badan Pengawas Obat dan Makanan Republik Indonesia* (BPOM), 2022). Nevertheless, the calculated nutrient contribution represents hypothetical adult profiles; therefore, the serving size and frequency of consumption should be adjusted according to individual energy requirements, nutritional status, physical activity level, clinical condition, and treatment regimen.

3.6 Production cost analysis

The production cost of formulation F2 was calculated based on the costs of raw materials, packaging, labor, overhead, and the predetermined profit margin. The detailed cost distribution is presented in Table 8.

Table 8. Production cost analysis F2 dim sum

Ingredient	Price (IDR)	Price (USD)	Quantity Purchased	Quantity Used in F2	Cost (IDR)	Cost (USD)
Jamaican cherry leaf extract	0	0.00	100 g	70 g	0	0.00
Rice flour	8,000	0.45	500 g	100 g	1,600	0.09
Tapioca starch	7,500	0.42	500 g	25 g	375	0.02
Chicken	11,000	0.61	100 g	60 g	6,600	0.37
Carrots	4,000	0.22	100 g	30 g	600	0.03
Wood ear mushroom	3,000	0.17	100 g	30 g	900	0.05
Mocaf	25,000	1.40	500 g	30 g	1,500	0.08
Egg	10,000	0.56	250 g	50 g	2,000	0.11

Ingredient	Price (IDR)	Price (USD)	Quantity Purchased	Quantity Used in F2	Cost (IDR)	Cost (USD)
Jamaican cherry leaves	0	0.00	100 g	15 g	0	0.00
Cutleaf groundcherry fruit	18,000	1.01	100 g	35 g	6,300	0.35
Greek yogurt	3,000	0.17	40 g	20 g	1,500	0.08
Red tomato	2,000	0.11	100	20 g	400	0.02
Dried chili peppers	2,500	0.14	15 g	5 g	833	0.05
Packaging	6,500	0.36	8 box	8 box	52,000	2.91
Total food costs					74,608	4.17
Labor costs (20%)					14,922	0.83
Overhead costs (20%)					14,922	0.83
Profit (20%)					14,922	0.83
Grand Total					119,373	6.67
Selling price per package					14,922	0.83
Estimated Price					15,000	0.84

Note*:* Data obtained from local market survey, 2026. IDR 17.900 = USD 1.

As shown in Table 8, the total cost of raw materials and packaging for one production batch was IDR 74,608 (USD 4,17). Labor costs, overhead costs, and the profit margin were each calculated at 20% of the raw material cost, resulting in an additional IDR 14,922 (USD 0,83) for each component. Consequently, the total production cost reached IDR 119,373 (USD 6,67) per batch. Cost-based pricing is an important strategy in food product development because it ensures that production expenses are covered while maintaining business profitability (Natasya & Lukman, 2024).

Based on a production yield of eight packages, the calculated selling price was IDR 14,922 (USD 0,83) per package, which was rounded to IDR 15,000 (USD 0,84) for practical marketing purposes. This selling price reflects the overall production cost, including raw materials, packaging, labor, overhead, and the predetermined profit margin.

The production cost analysis indicates that the developed dim sum has the potential to be economically feasible for small-scale production. The use of Jamaican cherry leaves, which are locally available at no cost, may reduce raw material expenses, while cutleaf groundcherry fruit contributes functional value to the product. Nevertheless, fluctuations in the prices of cutleaf groundcherry fruit, packaging materials, and other ingredients may influence future production costs. Therefore, optimizing raw material procurement and implementing efficient production strategies may help maintain product affordability and economic sustainability.

3.7 Study Limitations and future research

This study has several limitations. Nutrient composition was calculated based on the Indonesian Food Composition Table/*Tabel Komposisi Pangan Indonesia* (TKPI) 2020, while flavonoid content was estimated using data from peer-reviewed scientific literature rather than directly quantified through laboratory analysis. Therefore, the reported flavonoid values represent estimated concentrations and should not be interpreted as analytically measured values. Furthermore, antioxidant activity, glycemic response, and biological efficacy of the developed product were not evaluated. Food safety, microbiological quality, physicochemical stability, and shelf-life assessment were also beyond the scope of the present study, although these aspects are important considerations for functional food development and commercialization. Consequently, the potential health benefits discussed in this manuscript are based on previous scientific evidence and require further validation through experimental and analytical studies.

Future studies should include direct laboratory quantification of flavonoids, antioxidant activity assays, glycemic index determination, and food safety evaluations, including microbiological, physicochemical, and shelf-life analyses. In addition, in vitro, animal, and clinical studies are recommended to validate the biological effects of the developed product and provide stronger evidence regarding its efficacy, safety, and commercialization potential.

4. Conclusions

This study demonstrated that the F2 formulation, containing equal proportions of Jamaican cherry leaves (*Muntingia calabura* L.) and cutleaf groundcherry fruit (*Physalis angulata* L.) (50:50), provided the most favorable balance of sensory acceptability, nutritional characteristics, and estimated flavonoid content among the three formulations evaluated. The formulation also met the Indonesian regulatory requirements for a source of dietary fiber claim and demonstrated promising economic feasibility, indicating its potential as a locally sourced ready-to-eat functional snack alternative within dietary management strategies for individuals with Type 2 Diabetes Mellitus.However, the present findings are limited to product development and characterization, and the flavonoid content was estimated from published literature rather than determined through laboratory analysis. Therefore, these findings should not be interpreted as evidence of clinical efficacy, and further analytical studies using validated methods, together with preclinical and clinical investigations, are required to confirm the product's nutrient composition, bioactive compound content, safety, and potential role in the dietary management of Type 2 Diabetes Mellitus.

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Author Contribution

Conceptualization, S.D.D.A., A.Z.M., M.N.B., A.N.L., and D.A.; Methodology, S.D.D.A.; Formal Analysis, S.D.D.A.; Investigation, S.D.D.A., A.Z.M., M.N.B., A.N.L., and D.A.; Data Curation, S.D.D.A.; Validation, M.N.B.; Resources, M.N.B.; Writing – Original Draft Preparation, S.D.D.A. and A.Z.M.; Writing – Review & Editing, A.Z.M., A.N.L., D.A., and B.M.; Visualization, S.D.D.A.; Supervision, B.M.; Project Administration, S.D.D.A. All authors have read and agreed to the published version of the manuscript.

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Ethical Review Board Statement

Ethical review and approval were waived for this study because the research involved voluntary sensory evaluation of food products by adult panelists and posed no more than minimal risk to participants. No personal or sensitive data were collected.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used Grammarly to improve grammar, clarity, and readability. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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