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An innovative dim sum based on the synergy of insulin leaves (*Smallanthus sonchifolius*) and breadfruit flour substitution as a dual-action strategy for antihyperglycemic functional food

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ABSTRACT

Background: Indonesia ranks fifth in the world in terms of the number of cases of Type 2 Diabetes Mellitus (T2DM), with the majority of cases occurring in the working-age population, which accounts for 69.51% of Indonesia's total population. This is driven by changes in dietary patterns toward an unbalanced diet that is not offset by adequate physical activity. Various nutritional interventions and healthy lifestyle changes have been implemented, but the variety of healthy food options remains limited. Therefore, this study aims to examine and determine the characteristics and optimal conceptual formulation of adding yacon leaves (*Smallanthus sonchiofolius*) powder as a substitute for breadfruit flour in dim sum, as well as to explain the synergistic mechanism between the two in controlling blood glucose levels in the body. **Methods:** The method used in this study was a literature review, followed by data tabulation. The data were obtained through the Publish or Perish platform and consisted of review and experimental studies published between 2016 and 2026 from databases such as Google Scholar, PubMed, ScienceDirect, and others. **Findings:** The results of the study indicate that the optimal dim sum formulation involves the addition of 2% yacon leaves powder, with an upper limit of 5% to maintain sensory characteristics acceptable to consumers. Furthermore, the synergy between the bioactive compounds in yacon leaves powder and the fiber content in breadfruit flour demonstrates potential as a dual-action strategy to help control blood glucose levels. **Conclusion:** This innovation in yacon leaves - based dim sum using breadfruit flour substitution provides a potential functional food alternative for individuals at risk of or suffering from hyperglycemia. **Novelty/Originality of this article:** The uniqueness of this study lies in the combination of yacon leaves powder with breadfruit flour, which establishes it as a dual-action antihyperglycemic functional food strategy.

KEYWORDS: antihyperglycemic; breadfruit flour; functional food; type 2 diabetes mellitus; yacon leaves.

1. Introduction

More than half a billion people worldwide are facing a serious health crisis, namely living with Noncommunicable Diseases (NCDs). Among the various types of NCDs, the condition that plays a major role in global mortality rates is Type 2 Diabetes Mellitus (T2DM), a metabolic disease characterized by hyperglycemia resulting from abnormalities in insulin production, insulin section, or both (Magdalena et al., 2026). Data from the

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Ministry of Health of the Republic of Indonesia indicate that the number of people with diabetes worldwide has reached 537 million; this figure is projected to reach 643 million by 2030 and will continue to rise through 2045.

Data from the 2021 International Diabetes Federation (IDF) Atlas indicate that Indonesia ranks fifth globally in the number of people with diabetes, rising from an initial 6.9% to 8.5% (Tanati & Nurvita, 2025). Compared to 2019, the number of T2DM cases has nearly doubled in just two years (Rofie et al., 2022). While T2DM cases were previously dominated by the elderly, the working-age population now accounts for the majority. The working-age population refers to individuals aged 15–64 years (Amelia et al., 2024). According to the 2025 Final Population Data/*Data Konsolidasi Bersih* (DKB), the working-age population reached 199 million people, or 69.51% of Indonesia's total population (Dinas Kependudukan dan Pencatatan Sipil Kabupaten Ogan Komering Ulu, 2025). This indicates that Indonesia is facing a serious health threat, as the rise in T2DM cases is occurring among the working-age population, which currently dominates the national demographic structure.

The sharp increase in T2DM cases among the working-age population is due to changes in modern lifestyles and unbalanced dietary patterns (Putri et al., 2024). The current dietary patterns of the working-age population tend to be high in sugar, salt, and fat, but low in fiber. According to Susanti et al. (2024), these significant dietary changes have been identified as key contributors to the T2DM epidemic. Compounding this is a sedentary work culture, which requires people to spend hours sitting at a time, meaning that this excess calorie intake is not offset by meaningful physical activity (Fin et al., 2025). This leads to insulin resistance, in which the body's cells do not respond properly to insulin, resulting in elevated blood glucose levels (Widiastuti et al., 2024).

The steadily rising prevalence of T2DM not only affects individuals' physical health but also imposes a significant economic burden due to the need for care and a long-term decline in quality of life (Susanti et al., 2024). Diabetes at a young age can lead to prolonged exposure to hyperglycemia, increasing the risk of more severe cardiovascular conditions. This leads to chronic complications such as coronary heart disease, atherosclerosis, retinopathy, and other conditions that may occur earlier, before individuals reach old age (Purwandari et al., 2022). If this situation is allowed to continue, it is not unlikely that quality of life will decline, potentially leading to premature death. Therefore, effective and sustainable prevention efforts are needed to address this diabetes problem.

Among the various strategies for nutritional intervention and healthy lifestyle changes, choosing foods based on the glycemic index (GI) is a widely recommended approach because it can help control postprandial blood glucose levels. The glycemic index (GI) is a numerical value used to categorize carbohydrate-containing foods based on their effect on blood sugar levels. GI values range from 1 to 100, with GI ≤ 55 classified as low, GI 56–69 as moderate, and GI ≥ 70 as high (Atkinson et al. 2021; Yuliatun et al., 2023). In foods with a high GI, the breakdown of carbohydrates into glucose occurs more rapidly, which can cause fluctuations in blood glucose levels. Conversely, in foods with a low GI, the breakdown of carbohydrates occurs more slowly, resulting in more stable blood glucose levels (Sunani & Hendriani, 2023). In addition to the glycemic index, another important parameter to consider is the glycemic load (GL), which is a value indicating the body's blood glucose response after consuming a serving of food taking into account both the glycemic index and the amount of carbohydrates it contains (Wari et al., 2023). For individuals with diabetes mellitus who experience impaired insulin secretion or insulin resistance, chronic consumption of foods with high GI and GL values can worsen their clinical condition. Therefore, consuming foods with low GI and GL values is more recommended because they tend to produce a more stable glycemic response, thereby potentially aiding in the control of blood glucose levels in individuals at risk of or living with T2DM.

As public awareness of health has increased, so has the demand for functional foods. Today, people are not only looking for foods that are nutritious and delicious, but also foods that provide specific physiological benefits to the body. This growing interest in functional foods is also supported by the fact that research on functional foods has increased sixfold in

Indonesia over the past ten years (Khoerunisa, 2020). Functional food products with additional health claims are also being developed, such as foods with a low glycemic index and low sugar, fat, and salt content, which are expected to reduce the risk of Type 2 diabetes. However, the variety of these products is still limited to general food categories, such as cookies, bread, noodles, snacks, and functional teas. In fact, public interest in processed food products, especially those that are currently trending, is very high. This situation calls for more diverse innovations in the field of functional foods to engage people of all generations in efforts to prevent Type 2 diabetes.

One example of a food product that is currently very popular is dim sum. Dim sum is a dish that is typically steamed, made primarily from wheat flour and sago flour, with added chicken wrapped in a soft wrapper (Tiarisma & Hadi, 2025). Dim sum is a very popular food product among Indonesians. However, this product is generally low in fiber and dominated by carbohydrates from wheat flour, and it has a high sodium content, which has the potential to cause spikes in blood glucose levels in people with diabetes mellitus. Given this, this study was conducted to determine the optimal conseptual formulation for an innovative dim sum that incorporates insulin leaf powder and replaces wheat flour with breadfruit flour.

The strength of this dim sum innovation lies in the synergy between insulin leaf powder and breadfruit flour as a substitute ingredient. Insulin leaves were chosen as part of this innovation because they can lower blood glucose levels in people with diabetes thanks to their antioxidant content (Anggraini & Suharyanto, 2022). Meanwhile, breadfruit flour was chosen as an alternative to wheat flour because it is gluten-free, rich in carbohydrates, and contains dietary fiber that is beneficial to the body (Muhlishoh et al., 2021; Mehta et al. 2023). Furthermore, the selection of breadfruit flour can also serve as an effort to diversify local food sources to reduce dependence on wheat imports for wheat flour. Therefore, this study on the development of a concept for dim sum innovation based on the synergy of insulin leaves (*Smallanthus sonchifolius*) with breadfruit flour substitution as a functional food aims to address these issues.

Through this innovative dim sum product concept, the primary focus of this research is to achieve a balance between health benefits and consumer acceptance. The presence of insulin leaf, which naturally has a strong bitter taste, presents a unique challenge in processed food formulation. Therefore, it is important to conduct a more in-depth study on the characteristics and optimal conseptual formulation of the combination of insulin leaf powder with breadfruit flour as a substitute to produce sensory characteristics that are preferred and widely accepted by consumers. On the other hand, scientific evidence is also needed to understand the biochemical synergy between the active compounds in insulin leaf powder and the fiber content as well as the slowly digestible starch in breadfruit flour in lowering blood glucose levels in the body. Through this comprehensive approach, this innovative dim sum is expected to become a delicious and safe functional food alternative for glycemic management in people with diabetes mellitus.

2. Methods

2.1 Type of research

This study employed a qualitative descriptive method in the form of a literature review, which involves data collection by comparing information from various sources related to the variables under investigation. The research was conducted intensively through reflective analysis of the documents identified, followed by a detailed synthesis of the core information. The data used consisted of review studies and experimental studies based on the inclusion criteria, namely full-text data published in English or Indonesian.

As this is a literature review, it is not tied to a specific geographic location. The processes of searching for, collecting, and analyzing data were conducted online by accessing various reputable scientific databases. This research was conducted over a two-month period, from the month of March to April 2026. This period encompassed several stages of activity, ranging from brainstorming ideas, identifying topics, searching for and screening literature, analyzing data, to the manuscript drafting stage.

2.2 Data collection techniques

The data in this study were obtained from various sources, such as scientific journals, articles, and reliable publications relevant to the variables in this study. Keywords used during the search included insulin leaves, breadfruit flour, diabetes, functional foods, and other relevant terms. The sources used were limited to publications from the last ten years to ensure the information was up-to-date and relevant to current developments.

The data collection process was conducted through a series of systematic steps, beginning with the identification and search for sources. In this initial stage, a comprehensive literature search was conducted across various reliable databases using keywords highly relevant to the research variables. Next, a screening phase was conducted to evaluate the collected literature based on specific criteria, including its relevance to the topic, publication within the last 10 years (from 2016 to 2026), and its origin from credible sources. Finally, during the exploration and organization stage, the selected texts are read in depth so that important data excerpts can be noted and systematically grouped according to the specific focus of the variables under study.

2.3 Data processing

Data processing is carried out using data tabulation by organizing, compiling, and summarizing information from various relevant literature. This process aims to present data systematically, thereby facilitating the observation, comparison, and analysis of the collected data. Additionally, this method is used to identify similarities and differences in findings across sources, thereby enhancing the validity of the information used in the research. Through this structured compilation process, the synthesis of the study's findings can be carried out more effectively and comprehensively, resulting in more accurate interpretations that support the discussion and help achieve the research objectives.

2.4 Data analysis and synthesis

The tabulated data is then analyzed using the comparative analysis method by examining, comparing, evaluating, and interpreting various information obtained from relevant literature. The analysis is conducted to identify similarities, differences, relationships, and trends in research findings across sources, thereby yielding a more comprehensive understanding of the topic under study. Through this comparative process, information highly relevant to the research objectives is selected and used as the basis for the discussion. Next, data synthesis is performed by integrating the various analysis results into a systematic and integrated discussion framework. The synthesis results are then presented in the form of narratives, tables, or figures to facilitate data visualization, enhance reader understanding, and support a clearer and more comprehensive interpretation of the research results.

Conclusions are drawn deductively based on the results of in-depth analysis and synthesis of the collected data. This process is carried out by carefully considering the level of consistency, alignment, and comparison among the literature used, thereby producing a scientific conclusion that is valid, objective, and capable of comprehensively addressing the research question.

3. Results and Discussion

3.1 Characteristics and optimal formulation of insulin leaf-based dimsum with breadfruit flour substitution

This dimsum innovation is a functional food product that incorporates insulin leaf powder and replaces wheat flour with breadfruit flour, making it safer for those at risk of developing Type 2 diabetes. The difference between this innovation and regular dim sum lies in the ingredients used, specifically the addition of insulin leaf powder (*Smallanthus sonchifolius*) and breadfruit flour (*Artocarpus altilis*) as a substitute for wheat flour. The addition and substitution of these ingredients result in this dim sum having a lower glycemic index (GI) compared to regular dim sum. However, the production process for this innovative dim sum is generally the same as that for regular dim sum.

Table 1. Summary of previous research

Title (researcher, year)	Key findings	Equation	Difference
Bioactive Compounds of Insulin Leaves (*Smallanthus sonchifolius*) as DPP4 Enzyme Inhibitors in Insulin Signaling Mechanism for The Treatment of Type 2 Diabetes Mellitus: In Silico Study (Wardani et al., 2025)	Insulin leaves act as an antidiabetic agent because they contain the active compound 1,19-dihydroxy-2,6,10,14-phytatetraen-18-oic acid, which is capable of inhibiting the DPP-4 enzyme. Insulin leaves are also known to contain bioactive compounds, such as flavonoids, tannins, and saponins, which act as antioxidants to neutralize free radicals.	Insulin leaves are known as a medicinal plant with anti-inflammatory, antioxidant, and antidiabetic properties due to their bioactive compounds.	-
Production of Dry Powder from Moringa Leaves (*Moringa oleifera*) Using Different Temperatures and Storage Durations for Use as a Functional Food Supplement (Zainuddin & Hajriani, 2021)	The organoleptic properties of moringa (*Moringa oleifera*) leaf powder that were most preferred by the panelists were observed at the highest heating temperature, namely 65 °C for 7 hours. The results of the study indicate that the higher the temperature during the drying treatment, the more acceptable the resulting flavor was to the panelists.	Moringa leaves share similarities with insulin leaves in that both contain high levels of bioactive compounds, which give them a bitter taste. Based on these findings, insulin leaves were added in powder form in this study to minimize their bitterness and distinctive aroma.	The difference in this study lies in the variable used, namely moringa leaves.
The Effect of Adding Moringa Leaf Powder (*Moringa oleifera L.*) on the Physical, Chemical, and Sensory Characteristics of Tilapia (*Oreochromis niloticus*) Siomay (Arni et al., 2024)	The treatment involving the addition of 5% moringa leaf flour resulted in the following scoring test scores: texture 3.24 (chewy), flavor 4.54 (very characteristic of moringa), aroma 4.75 (very characteristic of	The treatment involving the addition of powder containing 5% bioactive compounds resulted in a bitter taste and a distinctive aroma that remained very pronounced.	The difference in this study lies in the variable used, namely moringa leaves.

	moringa), and color 4.87 (deep, dark green).

(Zainuddin & Hajriani, 2021; Arni et al., 2024; Wardani et al., 2025)

Based on several findings in Table 1, insulin leaves (*Smallanthus sonchifolius*) were selected as one of the ingredients in this innovative dim sum because they are known as a medicinal plant with anti-inflammatory, antioxidant, and antidiabetic properties (Wardani et al., 2025). However, the use of insulin leaves in this food product presents several sensory challenges, namely a slightly bitter taste due to the presence of bioactive compounds. To address this, the most suitable form of insulin leaf for inclusion in dim sum is powder. This form was chosen because the drying process used in the production of the powder minimizes the bitter taste (Zainuddin & Hajriani, 2021). Additionally, adding the leaf powder helps maintain the dough's moisture content more effectively, resulting in a texture that consumers prefer. According to a study conducted by Arni et al. on the addition of moringa leaf powder (2024), when 5% of the powder, which contains bioactive compounds, in this study derived from moringa leaves, was added, the resulting bitterness and distinctive aroma were still very pronounced. Given that moringa leaves and insulin leaves have similar flavors, both tend to be bitter, in this dim sum innovation, the conceptual optimal formulation for adding insulin leaf powder is estimated at 2% to preserve both the flavor quality and the content of bioactive compounds.

Theoretically, the bitter taste derived from phenolic compounds, alkaloids, and saponins cannot be eliminated because these compounds are bioactive components that help lower blood sugar levels (Cavallo et al. 2019). However, the synergy among the ingredients used in this dim sum Innovation can help balance the sensory characteristics of each ingredient. The characteristics produced by insulin leaf powder can be offset by several characteristics of breadfruit flour (Table 2).

Table 2. Comparison of sensory characteristics of breadfruit flour and wheat flour

Sensory aspects	Breadfruit flour	Wheat flour
Color	Darker	Lighter
Aroma	Slightly sweet	Tends to be neutral
Texture	Not very smooth	Smooth
Taste	Characteristic of breadfruit	Neutral

(Surachman et al., 2022)

Based on the data in Table 2, the use of breadfruit flour produces sensory characteristics that differ from those of wheat flour. In terms of color, breadfruit flour produces food products with a darker color compared to wheat flour. This is because breadfruit contains the enzyme polyphenol oxidase, which, upon contact with air, triggers a browning reaction, resulting in a darker color (Surachman et al., 2022). Based on hedonic testing and scoring in Surachman et al.'s (2022) study, panelists preferred all the resulting colors, ranging from cream to light brown.

In terms of texture, wheat flour produces a softer and smoother dough compared to breadfruit flour. This is because breadfruit flour contains 7.45% crude fiber, a much higher amount than wheat flour (Surachman et al., 2022). The crude fiber content in food products plays an important role in slowing the rate of blood sugar spikes after a meal. It is this high crude fiber content that sets this innovative dim sum apart from other dim sum varieties.

Another property of breadfruit flour that affects texture is its hydration capacity. Breadfruit flour has a hydration capacity of 290%, which is higher than that of wheat flour, which is only 191.55%. Hydration capacity refers to the amount of water that flour can absorb. The higher the hydration capacity, the more water the flour can absorb. This is consistent with research conducted by Surachman et al. (2022), who found that as the proportion of breadfruit flour increased, the resulting dough became thicker, as observed in the dough before steaming. Additionally, breadfruit flour is gluten-free, so the dough is

less elastic (Kristiningsih et al., 2022). To address this, eggs were added to the dim sum dough to act as a binder, ensuring the filling adheres well to the wrapper.

Although this innovation focuses on adding insulin leaf powder and substituting breadfruit flour, the success of the dim sum innovation is also supported by complementary ingredients commonly used in dim sum preparation, such as chicken and additional seasonings. The chicken meat here also helps mask the bitter taste of insulin leaves thanks to its savory flavor.

Meanwhile, common seasonings used in dim sum preparation include sesame oil, oyster sauce, soy sauce, minced garlic, scallions, salt, ground pepper, and mushroom broth. The addition of these seasonings not only enriches the flavor but also enhances the aroma, ensuring greater consumer acceptance of this dim sum innovation. Ingredients such as garlic and pepper help minimize unwanted flavors, while soy sauce and sesame oil add an umami dimension, ensuring that this dim sum innovation retains a flavor that is familiar to consumers. Based on the characteristics of these ingredients, the optimal formulation for this dim sum innovation has been determined (Table 3).

Table 3. Proposed conceptual dim sum filling formulation using insulin leaf powder and breadfruit flour substitution (based on a total dough weight of 500 g)

Ingredient	Percentage (%)	Weight (grams)
Chicken meat	60	300
Breadfruit flour	18	90
Insulin leaf powder	2	10
Chicken eggs	10	50
Garlic	2	10
Sesame oil	1	5
Oyster sauce	1	5
Salt	0.6	3
Ground pepper	0.4	2

In Table 3, the total weight of the main ingredients in this recipe is 475 grams. The remaining 25 grams is allocated for water to adjust the dough's consistency. The table does not list the added water as a main ingredient because the amount can be adjusted according to the desired consistency of the dough. The water aids in the mixing process, helps form the dough, and produces the optimal texture for both the dim sum wrappers and the filling.

The practical implications of this innovation open up new opportunities for industry players and Small and Medium-sized Enterprises (SMEs) to develop low-glycemic functional food products using locally sourced ingredients. This formulation can be directly applied at a medium-scale production level without requiring complex modifications to production equipment or compromising the quality that consumers value. However, the development of this formulation is still limited to information obtained from a literature review; therefore, organoleptic testing and further formulation development are needed to align with consumer acceptance.. Development in the field of food processing is also strongly recommended in order to develop products with a longer shelf life.

3.2 Bioactive compounds in insulin leaves as an antihyperglycemic agent

Insulin leaves (*Smallanthus sonchifolius*), also known as the yakon plant, are a type of herbal plant with potential as an antidiabetic agent (Baroni et al., 2016; Contreras-Puentes & Alviz-Amador, 2020). The leaves of this plant are known to contain various bioactive compounds that play a role in pharmacological activity, particularly in blood glucose control. Insulin leaves contain sesquiterpene lactones, chlorogenic acid, and flavonoids as active compounds that have the potential to lower blood sugar levels. This is consistent with the research by Syafitri et al. (2026), in which the results of a phytochemical screening of an ethanol extract of insulin leaves showed the presence of active compounds such as alkaloids, flavonoids, saponins, tannins, and steroids. Flavonoids, particularly quercetin, are known to

possess antioxidant and antidiabetic activities that can play a positive role in repairing pancreatic beta cells and enhancing insulin secretion (Syafitri et al., 2026).

In addition to flavonoids, insulin leaves are also known to contain saponins, tannins, and steroids that support their potential as antidiabetic agents. This plant also contains phenols, chlorogenic acid, caffeoylquinic acid, ferulic acid, fructooligosaccharides, and flavonoids that can lower blood glucose levels. The chlorogenic acids present in insulin leaves can inhibit the enzyme glucose-6-phosphatase, thereby inhibiting gluconeogenesis and glycogenolysis, which in turn lowers blood glucose levels (Naveed et al., 2018; Widiastuti et al., 2022). In addition to their hypoglycemic effects, insulin leaves also possess antioxidant activity that can help reduce oxidative stress in people with diabetes (Rojas et al., 2018). Therefore, consuming natural substances with antioxidant activity, such as insulin leaves, can provide additional benefits in the management of T2DM (Utami & Lena, 2022). Overall, the bioactive compounds in insulin leaves provide significant benefits for blood glucose levels. This is consistent with previous research by Triastuti et al. on diabetic rats, which demonstrated the effectiveness of insulin leaf extract in lowering blood glucose levels, as summarized in (Table 4).

Table 4. Blood glucose levels in mice under various treatment regimens involving insulin leaf extract supplementation

Treatment group	Average glucose level pre-test (mg/dl)	Average glucose level post-test (mg/dl)
Control	223.43	223
Administration of 200 mg/kg body weight of insulin leaves	219.57	183.71
Administration of 300 mg/kg body weight of insulin leaves	211.43	173.71
Administration of 500 mg/kg body weight of insulin leaves	211.14	162.29

(Triastuti et al., 2020)

Based on the data in Table 4, the treatment with an additional dose of 500 mg/kg body weight of insulin leaf extract successfully reduced the average blood glucose level from an initial 211.14 mg/dl in the pre-test to 162.29 in the post-test. A study conducted by Syafitri et al. (2026) also showed similar results, in which the administration of ethanol extract of insulin leaves was found to reduce blood glucose levels in male Wistar rats induced with a combination of nicotinamide and streptozotocin. In their study, administration of insulin leaf ethanol extract at a dose of 400 mg/kg body weight successfully reduced blood glucose levels after 28 days of treatment, with a reduction rate of 56.78%. This was found to be equivalent to the standard antidiabetic drug, glibenclamide, which reduced blood glucose levels by 57.08%. These two results indicate no significant difference, meaning that the addition of insulin leaves has been shown to have the potential to be developed as an alternative in the treatment of diabetes (Syafitri et al., 2026).

3.3 The role of breadfruit flour in controlling the glycemic index and glycemic load

Breadfruit is a local food with health benefits. It has a relatively high carbohydrate content, making it a good source of energy (Hendrawan, 2024). The carbohydrate content in breadfruit reaches 84%, with starch accounting for 68.38–69.20%. In addition, breadfruit also contains 4.31–4.85% crude protein, 5.00–5.38% crude fiber, 2.11–2.90% fat, and 2.56–2.90% ash. The energy content of breadfruit from Java reaches 136.40 cal/100 g, which is higher than that of breadfruit from outside Java, which ranges only from 41.19–106 cal/100 g (Arnold et al., 2017).

Breadfruit flour is one of the gluten-free processed forms of breadfruit. Breadfruit flour contains complex carbohydrates, which have long sugar chains, resulting in a more stable release of energy (Arnold et al., 2017). This flour also has a relatively high calcium and phosphorus content. Furthermore, breadfruit flour is known to have a relatively high dietary fiber content and has the potential to be a healthier food ingredient compared to other flours (Sukandar et al., 2014). This fiber content is known to play a role in supporting healthier dietary patterns, particularly in managing blood glucose levels (Weickert & Pfeiffer, 2018; Puspikasari & Akbar, 2024). The nutritional composition of sukun flour generally differs from that of wheat flour (Table 5).

Table 5. Comparison of moisture content, ash content, protein content, fat content, carbohydrate content, and fiber content between breadfruit flour and wheat flour

Component	Breadfruit flour (%)	Wheat flour (%)
Moisture content	9.85	11.8
Ash content	1.94	1.00
Protein content	3.50	13.00
Fat content	0.58	1.00
Carbohydrate content	84.13	77.2
Crude fiber content	7.45	0.3

(Surachman et al., 2022)

The data in Table 5 confirm that breadfruit flour has a higher fiber content compared to wheat flour. The high crude fiber content in breadfruit flour indicates a high soluble fiber content, which plays a crucial role in forming a gel matrix in the small intestine to inhibit glucose adsorption. Breadfruit flour contains 3.53% soluble fiber, which is higher than that of wheat flour, which has a low fiber content (Chandra et al., 2021). Meanwhile, its insoluble fiber content reaches 7.33% (Wulandari et al., 2016). The soluble fiber content in breadfruit flour plays a key role in the digestive tract by slowing gastric emptying time. Overall, fiber acts as a physical barrier preventing glucose from reaching the intestinal wall (Nursalam et al., 2016). As a result, blood glucose levels rise more gradually.

In addition to its high fiber content, another advantage of breadfruit flour is that it has a lower glycemic index (GI) than wheat flour, so it does not trigger a drastic increase in blood glucose levels after consumption. The glycemic index (GI) is a number used to categorize carbohydrate-containing foods based on their effect on blood sugar levels. GI values range from 1 to 100, with GI ≤ 55 classified as low, GI 56–69 as moderate, and GI ≥ 70 as high (Yuliatun et al., 2023). In foods with a high GI, the breakdown of carbohydrates into glucose occurs more rapidly, which can cause fluctuations in blood glucose levels. Conversely, in foods with a low GI, the breakdown of carbohydrates occurs more slowly, resulting in more stable blood glucose levels (Sunani & Hendriani, 2023).

Meanwhile, glycemic load (GL) is a value that indicates the body's blood glucose response after consuming a single serving of a carbohydrate-containing food (Wari et al., 2023). GI and GL do not always correlate directly. Foods with a high GI can have a low GL if consumed in small amounts. However, foods with a low GI can have a high GL if consumed in large quantities. The higher the carbohydrate content in a food product, the greater the potential for a high GL in that product. High GI and GL values can increase the risk of T2DM because they can stimulate increased insulin production and lead to hyperinsulinemia (Sunani & Hendriani, 2023).

Breadfruit-based foods have a glycemic index ranging from low to moderate—approximately 23–60 making them a potential be used as an alternative carbohydrate source for people with T2DM (Fauziana et al., 2025). This low GI characteristic indicates that the carbohydrate structure in breadfruit flour takes longer to break down into glucose during digestion. This prolonged and stable absorption process effectively prevents drastic spikes in blood glucose (glucose spikes), which are typically triggered by flours with high GI content. Nevertheless, consumption of breadfruit flour must still be moderated to ensure that blood glucose levels do not spike.

3.4 The mechanism for regulating blood glucose levels through a dual-action synergy in Dimsum

Blood glucose levels refer to the amount of glucose present in the blood. Normal blood glucose levels are generally below 200 mg/dL, while fasting blood glucose levels are usually less than 126 mg/dL. Under normal conditions, blood glucose levels rise after eating and remain elevated for a short period of time (Oktaviani et al., 2021). Typically, after consuming foods containing carbohydrates, blood glucose levels will rise (Utami *et al.,* 2024).

Carbohydrate metabolism after a meal (the postprandial phase) begins in the digestive tract, where complex carbohydrates from food are broken down mechanically and chemically by the enzyme amylase in the mouth (Kashtoh & Baek, 2022). This is followed by further breakdown by disaccharidase enzymes in the small intestine into the simplest molecule: glucose. The glucose resulting from this digestion is then absorbed through the small intestinal wall and enters the bloodstream, which automatically causes blood glucose levels to rise (Papakonstantinou et al., 2022).

This rise in blood sugar levels is immediately recognized as an emergency signal by the pancreatic beta cells, prompting them to rapidly produce and secrete the hormone insulin into the bloodstream. The released insulin then circulates throughout the body and acts as a key by binding to specific receptors on the surface of target cells, primarily skeletal muscle cells and adipose (fat) tissue. This binding triggers an intracellular signal that instructs a mechanical transporter called GLUT4 to move toward the cell membrane, open the gate, and allow glucose to enter from the bloodstream into the cell (Chadt & Al-hasani, 2020).

Once it has successfully entered the cell, glucose is immediately converted into energy (ATP) through glycolysis to support the body's cellular activities. At the same time, high insulin levels in the blood send a signal to the liver to halt internal glucose production (the processes of gluconeogenesis and glycogenolysis) to prevent an overlap in the body's sugar supply. Through this highly organized distribution and storage process, most blood glucose is cleared from the bloodstream, so that within two hours after a meal, blood glucose levels gradually return to stable levels (Fiamoncini et al., 2022).

The problem is that in people with T2DM, this mechanism for lowering blood glucose levels after eating is disrupted due to insulin resistance. This is characterized by a decrease in tissue sensitivity to insulin, so the body requires higher insulin levels to maintain normal blood glucose levels. In the long term, this condition can lead to dysfunction of the pancreatic β-cells, resulting in elevated blood glucose levels, or hyperglycemia (Antoni, 2023). This condition is caused by the body's cells' inability to respond to insulin, so glucose cannot enter the cells and remains in the bloodstream (Prasetyo, 2025).

In people with T2DM, insulin resistance makes it difficult for the liver to regulate glucose production. As a result, the liver loses its sensitivity in regulating endogenous glucose production. Consequently, the liver continuously undergoes glycogenolysis (the breakdown of glycogen) and gluconeogenesis (the formation of new glucose), thereby triggering hyperglycemia or elevated blood glucose levels (Jung et al., 2024). Therefore, Dimsum's innovation utilizes bioactive compounds found in insulin leaves and the high fiber content in breadfruit flour to regulate these carbohydrate mechanisms, thereby helping to maintain more stable blood glucose levels.

This blood glucose control mechanism through Dim sum's dual-action strategy, based on insulin leaves and breadfruit flour substitution occurs via two main pathways: the digestive tract and the liver. Starting in the digestive tract, this control mechanism occurs through the inhibition of the α-glucosidase enzyme in the small intestine. When consuming foods containing complex carbohydrates, such as starch and flour, the body cannot absorb them immediately. This is because the body does not immediately break down complex carbohydrates into glucose. These carbohydrates must first be broken down into oligosaccharides, and only then converted into monosaccharides (glucose). This breakdown

into glucose is carried out by the enzyme α-glucosidase found in the small intestine (Giuntini et al., 2022).

As previously explained, insulin leaves contain saponins and flavonoids that act as active compounds. The saponins and flavonoids in these leaves function as α-glucosidase inhibitors (AGI), which bind to the active site of the α-glucosidase enzyme. As a result, the enzyme's activity is inhibited, and the breakdown of oligosaccharides into glucose slows down or even stops. This reduces the amount of glucose entering the bloodstream, thereby minimizing postprandial blood sugar spikes. Additionally, the flavonoids found in insulin leaves can neutralize free radicals, thereby helping to reduce cellular damage and inflammation (Triastuti et al., 2020).

Not only that, but insulin leaves also contain tannins, which play a crucial role in this digestive pathway. These compounds act as guardians in the digestive tract to ensure that not all glucose produced from food immediately enters the bloodstream. Similar to saponins, tannins work by binding to carbohydrate-digesting enzymes in the intestines, thereby inhibiting or even neutralizing their activity. As a result, food is not rapidly converted into glucose (Marghich et al., 2022).

Additionally, this metabolic regulation is supported by the dietary fiber and resistant starch content in breadfruit flour. Glucose regulation by dietary fiber occurs through a synergistic interaction between soluble and insoluble fiber, which act at different stages of digestion. This mechanism begins with the role of insoluble fiber in breadfruit flour, which acts like a protective network within the digestive tract. This fiber network works by trapping or enveloping the carbohydrates present in the dimsum dough (Edwards et al., 2021). As a result of this encapsulation, digestive enzymes have difficulty reaching and breaking down complex carbohydrates into simple sugars (glucose). Consequently, the process of breaking down complex carbohydrates into glucose is inhibited from the very beginning of digestion (Chi et al., 2022).

Furthermore, this mechanism is reinforced by the role of soluble fiber, which acts in the stomach and small intestine. This occurs because breadfruit flour absorbs water to form a thick gel matrix that slows gastric emptying, allowing food to be gradually released into the small intestine. Once in the small intestine, this thick gel acts as a physical barrier that coats the intestinal walls. This physical barrier then traps glucose molecules—which have been broken down from food, within the gel's network. As a result, the glucose cannot easily enter the bloodstream. It is absorbed into the bloodstream slowly and gradually, more effectively preventing extreme postprandial blood sugar spikes (Lu et al., 2019).

On a different note, under normal conditions, the liver is responsible for maintaining stable blood glucose levels when the body is not receiving food. To prevent fatigue, the liver normally produces glucose on its own through the processes of glycogenolysis and gluconeogenesis. Glycogenolysis is the breakdown of glycogen stores into glucose, while gluconeogenesis is the formation of new glucose from non-carbohydrate precursors, such as pyruvate and lactate. Both processes require the enzyme glucose-6-phosphatase, which specifically converts glucose-6-phosphate into glucose (Rajas et al., 2019). This process then results in the release of glucose into the bloodstream, ensuring the body continues to receive energy. However, in people with diabetes, this process is often uncontrolled, causing blood sugar levels to remain high even when no food is consumed (Petersen et al., 2017).

This is where the addition of insulin leaves plays a crucial role. In the hepatic pathway, the chlorogenic acids present in insulin leaves can inhibit the glucose-6-phosphatase enzyme, thereby directly inhibiting gluconeogenesis and glycogenolysis. When the glucose-6-phosphatase enzyme is inactive, glucose cannot be produced in the liver and cannot be released into the bloodstream, thereby lowering blood glucose levels (T. C. Widiastuti et al., 2022). Additionally, phenols and ferulic acid act as a protective shield for the pancreas. Both are capable of neutralizing toxins and free radicals that attack the pancreas due to excessive strain. As a result, the pancreas which serves as the body's natural blood sugar regulator—does not experience fatigue or damage (Kose et al., 2023).

This series of biochemical interactions demonstrates that the substitution of breadfruit flour with insulin leaf powder in this dim sum innovation does not function in isolation; rather, the two components complement each other within an integrated regulatory system. The advantage of this mechanism lies in its ability to simultaneously intervene in carbohydrate metabolism pathways from two directions. While the soluble and insoluble fiber from breadfruit flour acts as a mechanical barrier upstream, trapping starch and slowing sugar absorption in the digestive tract, the bioactive compounds from insulin leaves work downstream to correct hormonal imbalances at the tissue level, halt uncontrolled sugar production in the liver, and protect the pancreas from the risk of functional damage. Through the coordinated action of the physical protection provided by fiber and these bioactive interventions, this dim sum innovation effectively suppresses post-meal blood sugar spikes, a common problem for people with T2DM, while offering a preventive and holistic approach to glycemic management right at the dinner table (Fig. 1). Although, in theory, combining the two would yield positive results, clinical trials—both in vivo and in vitro, are still needed to evaluate their safety and effectiveness in lowering blood glucose levels.

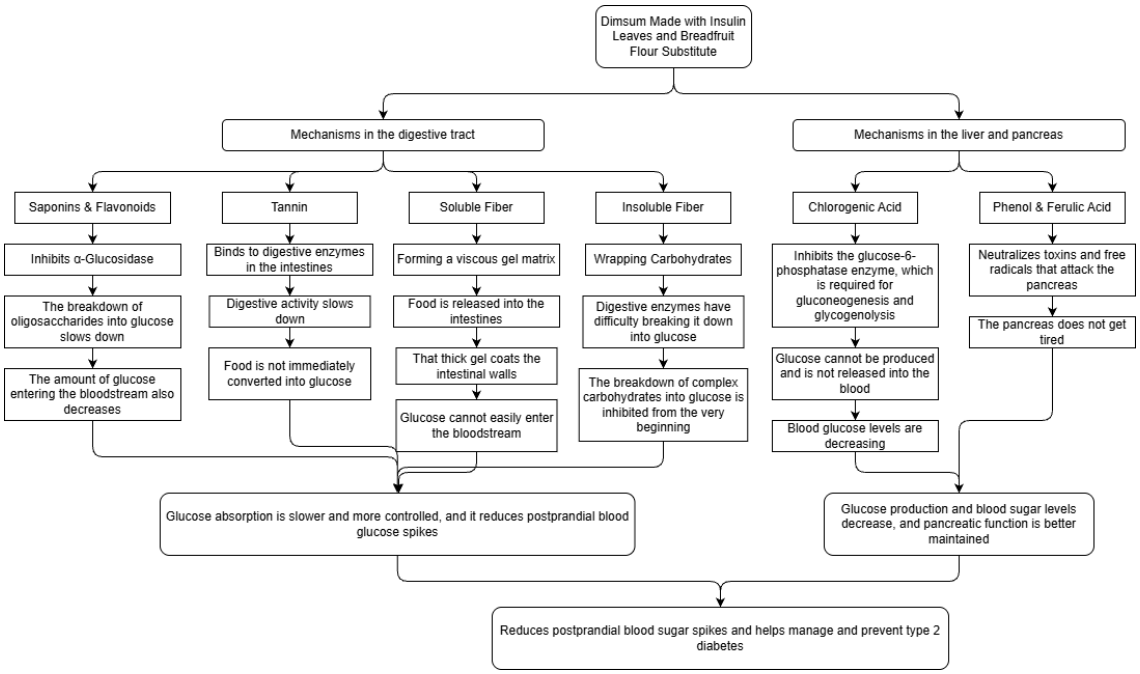

Fig. 1. Dual-action antihyperglycemic mechanism

4. Conclusions

Based on the research results, it can be concluded that the optimal formulation of insulin leaf powder is at an addition level of 2% to maintain sensory characteristics acceptable to consumers. Furthermore, the synergy between insulin leaf powder and breadfruit flour substitution shows potential as a dual-action strategy to help lower blood glucose levels. Bioactive compounds in insulin leaves, such as flavonoids and polyphenols, play a role in improving insulin sensitivity and inhibiting glucose absorption, while fiber-rich breadfruit flour serves to slow down the digestion and absorption of carbohydrates. The combination of these two ingredients produces a synergistic effect that supports more effective glycemic control. Thus, this innovation—insulin leaf-based dim sum with breadfruit flour substitution—can be categorized as a functional food innovation that not only meets nutritional needs but also provides health benefits, particularly as a dietary alternative for individuals at risk of or suffering from hyperglycemia. However, this study is

still limited to a literature review and has not yet involved direct testing. Therefore, further testing is needed to validate its safety and effectiveness.

Based on the study conducted, it is recommended that hedonic testing be performed to determine the nutritional content of the dim sum, as well as organoleptic testing to evaluate consumer acceptance of the dim sum. In addition, further in vivo and in vitro testing is needed to confirm the effectiveness of this dim sum innovation in directly lowering blood glucose levels in humans. Furthermore, product development should focus on improving the taste, particularly by reducing the distinctive taste of insulin leaves, so that this product will be more widely accepted by consumers. Future research is also expected to examine the product's shelf life and explore combinations with other functional food ingredients to enhance its antihyperglycemic benefits. Furthermore, an analysis of economic aspects and market opportunities is crucial to support the commercialization potential of this product as a functional food innovation.

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Author Contribution

R.A.: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – original draft; Writing – review & editing; Visualization; Project administration.

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Ethical Review Board Statement

This study did not require ethical approval because it was conducted using secondary data derived from published scientific literature. This study did not involve human participants, laboratory animals, or personally identifiable data.

Informed Consent Statement

Participant consent is not required because this study uses only published literature and does not involve humans, personal data, or direct interaction with individuals.

Data Availability Statement

All data underlying the findings and results of this study have been fully integrated into this document. No other external datasets were created or analyzed during the course of the study.

Conflicts of Interest

The author declare no conflict of interest.

Declaration of Generative AI Use

During the writing of this paper, the authors used Gemini to assist with translation, align the logical flow between paragraphs, and refine the clarity of the terminology and scientific structure of the manuscript. After using this tool, the authors independently conducted a review, in-depth editing, and verification of data from the literature. The authors bear full responsibility for the scientific validity and the entire content of this publication.

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