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Sundish flakes: An innovation in local-ingredient flakes made from breadfruit flour and pigeon pea flour as a supplementary feeding program for children

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ABSTRACT

Background: Stunting is a chronic nutritional condition that remains a significant public health concern in Indonesia, particularly among children under five years of age. Effective prevention requires appropriate nutritional interventions through supplementary feeding that is nutrient dense, higher in protein, affordable, acceptable to children, and supported by scientific evidence. Many existing supplementary feeding products are still less favored because their taste, aroma, and texture do not align with children's preferences and their use of local food resources remains limited. **Methods:** This study employed a Completely Randomized Design with five formulations of pigeon pea flour and breadfruit flour in flakes production, followed by sensory evaluation, texture, and color analyses to determine the best treatment. The selected formulation was further analyzed for protein, moisture, and ash contents using Kjeldahl and gravimetric methods, while the data were statistically evaluated using ANOVA, DNMRT, and independent t-test. **Findings:** Products were formulated in five proportions of breadfruit flour to pigeon pea flour, namely (85%:15%, 70%:30%, 55%:45%, 40%:60%, and 25%:75%). Sensory evaluation on color, aroma, texture, taste, and overall acceptance was conducted by 25 panelists and analyzed using Analysis of Variance followed by Duncan New Multiple Range Test at a five percent significance level. The most preferred formulation was further analyzed for protein, ash, and moisture content and compared with commercial supplementary feeding flakes using Independent t-test analysis. The formulation containing 40% breadfruit flour and 60% pigeon pea flour obtained the highest scores for texture, taste, and overall acceptance and showed favorable chemical characteristics with protein 10.543%, ash 2.38%, and moisture 5.27%, with protein significantly higher than commercial products which contain 7.173%. **Conclusion:** These findings indicate that Sundish Flakes has promising nutritional quality and sensory acceptance, making it relevant to support efforts in stunting prevention through improved local food utilization. **Novelty/Originality of this article:** This study develops a high-protein supplementary cereal from locally sourced breadfruit and pigeon pea flours to improve sensory acceptance and nutritional quality for stunting prevention among Indonesian children.

KEYWORDS: breadfruit; flakes; pigeon pea; stunting; supplementary feeding program.

1. Introduction

Child malnutrition is a major public health challenge in Indonesia, with stunting being the most common form of chronic malnutrition in early childhood. Stunting occurs when intake of essential nutrients, particularly protein and energy, remains insufficient for long

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periods of time, impairing linear growth, cognitive development, and immune function. Based on the 2024 Indonesian Nutritional Status Survey/*Survei Status Gizi Indonesia* (SSGI), the prevalence of national stunting fell to 19.8 percent or the equivalent of 4,482,340 toddlers. This is a 1.7 percent decrease compared to 2023, which was 21.5 percent. A total of 377,000 new cases of toddler stunting were also prevented. However, this result still exceeds the 2020–2024 National Medium-Term Development Plan/*Rencana Pembangunan Jangka Menengah Nasional* (RPJMN) target of 14 percent. Malnutrition interacts with limited food access, feeding practices, and household food environments, highlighting the need for more effective strategies to support child growth and health (Ministry of Health, 2023).

Government initiatives include the Supplementary Feeding Program/*Pemberian Makanan Tambahan* (PMT), which aims to increase children's nutritional intake through foods rich in energy, protein, vitamins, and minerals. Protein Micronutrient Technology (PMT) addresses nutritional gaps in children at risk of malnutrition. However, implementation challenges remain, as some children reject the product due to taste, aroma, or texture, resulting in low consumption and limited nutritional impact (Putri & Mahmudiono, 2020). Sensory acceptance has emerged as a critical determinant of whether PMT products achieve desired nutritional outcomes.

Flakes offer a promising solution due to their crunchy texture, mild sweetness, familiar shape, and convenience as a ready-to-eat cereal. Flakes are typically produced using corn and tapioca flour. However, to support food diversification programs, it is necessary to develop flakes that utilize local foods high in energy and protein, such as cereals, tubers, and legumes. Flakes allow flexible modification of raw materials, allowing for the addition of nutrient-rich local ingredients. Breadfruit (*Artocarpus altilis*) is a tropical plant with potential as a local food ingredient due to its high carbohydrate content and year-round availability. Research by Bustillos et al. (2025). The results showed that flakes made with a specific proportion of breadfruit flour had adequate expansion and texture values and were sensorially acceptable to panelists, demonstrating breadfruit's potential as a functional and safe breakfast cereal ingredient.

However, breadfruit flour still has nutritional deficiencies that need to be addressed when developed into functional food products such as flakes. Generally, breadfruit flour has a low protein content because breadfruit is a dominant source of energy (carbohydrates) rather than protein, resulting in the final flakes tending to fall short of meeting the body's protein needs. This means that the nutritional content of breadfruit flakes does not meet functional food product standards, especially for supplementary feeding programs (PMT), which require a balance of energy and protein. To address these limitations, the use of legume-based foods such as pigeon peas (*Cajanus cajan*) is an innovative alternative to improve the quality of breadfruit flakes. Pigeon peas are a local legume known in Bali as undis. Pigeon peas provide approximately 24.32 percent protein, serving as a valuable source of plant-based protein, while breadfruit provides carbohydrates essential for energy (Ginting et al., 2020; Parwata & Mariani, 2022). This combination of ingredients can produce flakes with a balanced macronutrient composition suitable for children. Scientific studies support the feasibility of this formulation. Pratiwi et al. (2025) showed that increasing the proportion of pigeon pea meal in flakes significantly increased protein content. Kurniasari et al. (2025) found that a combination of breadfruit flour and mocaf flour in a ratio of 30 to 70 produced flakes with 5.41 percent protein, meeting Indonesia National Standar/*Standar Nasional Indonesia* (SNI) standard 01-4270-1996. These results confirm that local ingredient-based formulations can achieve comparable quality to commercial grain-based cereals, providing a solid basis for functional food development for children.

Sundish developed from this scientific basis, using breadfruit and undis as the main ingredients. This product provides high protein content and sensory qualities designed to be accepted by children. Formulations take into account taste, aroma, texture, and color, ensuring taste without sacrificing nutritional benefits. Sundish encourages the utilization of underutilized local commodities, strengthens community-based food systems and reduces dependence on imports (Sihombing, 2023).

Evaluation involves comparison with commercial flakes to assess nutritional and sensory superiority. Comparative analysis demonstrated Sundish's potential to compete in nutritional composition, acceptability, and suitability as a PMT (Preventive Medical Technology) product. Evidence supports its role as a nutritious alternative that is locally sourced and contributes to stunting prevention. These findings provide information about areas that need improvement, ensuring a real impact on child nutrition in Indonesia. Sundish contributes to the Sustainable Development Goals, including SDG 2 Zero Hunger, SDG 3 Good Health and Well-Being, SDG 9 Industry, Innovation and Infrastructure, and SDG 12 Responsible Consumption and Production (Agri et al., 2024), strengthening its role as an innovative product that supports sustainable nutritional development towards a Golden Indonesia 2045.

1.1 Supplementary feeding program for children

Ensuring adequate nutrition during early childhood is essential, as this period represents a critical phase that determines children's health, development, and quality of life in the future. Children aged 6–59 months are highly vulnerable to deficiencies in energy and protein, thereby requiring appropriate, structured, and sustainable nutritional interventions. One of the major efforts implemented to address this issue is the Supplementary Feeding Program (PMT), which aims to support children's daily nutrient intake through the provision of safe foods with adequate nutritional value that are suitable for their physiological needs (Salsabila et al., 2023). However, in practice, many PMT products currently available are still dominated by wheat-based formulations, creating dependency on non-local ingredients and limiting the utilization of regional food resources. This condition highlights the need for innovation in developing locally based PMT products that possess high nutritional value, better sustainability, and stronger contribution to national food resilience (Adi et al., 2024). To date, PMT is generally provided in the form of ready-to-eat meals or snack preparations such as mung bean porridge, corn porridge, milk pudding, or biscuits, which have long been used in child nutrition programs (Depiyana et al., 2024). Although these products are widely familiar, recent developments indicate that modern preparations such as cereals or flakes are increasingly considered a promising alternative because they are practical, easy to prepare, easy for children to consume, allow the incorporation of local food ingredients as sources of energy and protein, and have a relatively longer shelf life, making them more efficient in storage and distribution. Beyond nutritional adequacy, the success of PMT is also strongly influenced by children's sensory acceptance; attributes such as taste, aroma, and texture play a crucial role in determining children's willingness to consume the product regularly, and nutritionally adequate foods that are not sensorially accepted often fail to deliver optimal benefits.

In line with this, the utilization of locally sourced, energy-dense ingredients in flakes formulation has become increasingly relevant. One promising option is breadfruit (*Artocarpus altilis*), which is recognized as a high-carbohydrate local food source with nutritional characteristics supporting its application in functional food development. Recent research demonstrated that the incorporation of breadfruit flour into extruded flakes not only enhanced nutritional and functional properties but also produced products with good physical quality and high sensory acceptance, reflected by an overall liking score of approximately 7.9, indicating strong consumer preference and suitability for children's consumption (Bustillos et al., 2025). These findings suggest that breadfruit flour has potential to be utilized as a local ingredient in PMT-oriented cereal products, primarily as an energy source; however, to achieve a nutritionally balanced formulation that meets children's needs, such products should be complemented with high-protein ingredients such as legumes. Therefore, developing flakes-based PMT products from local food ingredients with adequate nutritional quality and strong sensory acceptance represents a strategic effort to produce foods that are not only nutritious but also appealing and consistently consumed by children. With well-designed implementation, continuous growth monitoring, and strengthened nutrition education for parents, PMT holds great potential as a long-term strategy to reduce the risk of malnutrition, lower stunting prevalence, and support optimal child growth and development (Sinaga et al., 2023).

1.2 Flakes

Flakes are ready-to-eat dry food products commonly consumed at breakfast because they are practical and compatible with a fast-paced modern lifestyle (Rani et al., 2021). These products are generally made from cereals such as corn, rice, or wheat, and may also utilize alternative ingredients such as tubers that are processed through drying and flaking to produce thin, crispy pieces that are easy to rehydrate (Gionte et al., 2022). In Indonesia, the quality of flakes is regulated by the Indonesian National Standard SNI 01-4270-1996, which requires normal taste and aroma, a maximum moisture content of 3%, maximum ash content of 4%, a minimum protein level of 5%, minimum fat of 7%, minimum carbohydrate content of 60%, and a maximum crude fiber content of 0.7%. Furthermore, the standard prohibits the use of certain artificial sweeteners such as saccharin and cyclamate to ensure product safety and consumer protection (Rani et al., 2021).

In practice, many commercially available flakes are formulated with emphasis on convenience and sensory appeal, leading to relatively high sugar content and the use of various food additives. Although this formulation supports consumer preference, it is less ideal when flakes are considered as a food source to support children's nutritional needs in the long term. For this reason, flakes are increasingly being developed not only as breakfast foods but also as more functional products with potential application in Supplementary Feeding Programs (PMT). To achieve this function, reformulation efforts are required, including reducing sugar levels, limiting unnecessary additives, and selecting raw materials with higher nutritional value (Mulyanita et al., 2023). One strategic approach is the use of local food ingredients such as non-wheat cereals, tubers, and legumes, which can improve energy and protein content while supporting the utilization of local food resources. With their easy-to-consume form, good storage stability, and high likelihood of sensory acceptance among children, reformulated flakes are considered relevant to be further developed as locally based PMT products.

1.3 Pigeon pea

Pigeon pea (*Cajanus cajan* L.), commonly known in Bali as undis, is a tropical legume with high nutritional value and is widely utilized in food formulation. This legume is recognized as a source of plant-based protein, complex carbohydrates, dietary fiber, vitamins, minerals, and various bioactive compounds such as flavonoids, polyphenols, saponins, and phenolic compounds, all of which contribute to antioxidant activity and potential health benefits. In flour form, pigeon pea is widely acknowledged as an ingredient capable of improving the nutritional quality of various food products, particularly due to its relatively high protein content compared to many other plant-based sources (Parwata & Mariani, 2022). The use of pigeon pea flour as a substitute for wheat flour is considered highly feasible, especially in the development of functional foods and products aimed at improving nutritional intake. Preliminary processing steps such as peeling, boiling, and soaking have also been reported to reduce antinutritional compounds while improving sensory characteristics including taste, color, and texture, thereby enhancing consumer acceptability (Sine & Soetarto, 2020).

Several studies have demonstrated the potential of pigeon pea in food product development. Pratiwi et al. (2025) reported that a combination of 55% arrowroot flour and 45% pigeon pea flour (treatment K5) was identified as the best formulation, producing flakes with moisture content of 3.04%, ash content of 2.07%, protein content of 8.79%, fat content of 8.27%, and carbohydrate content of 77.80%. The product also exhibited good sensory quality, characterized by preferred texture, attractive color, acceptable aroma, and taste that was well liked by panelists. These findings indicate that the incorporation of pigeon pea flour can improve the nutritional quality of flakes without reducing sensory acceptance. This finding is further supported by Suriani & Masdarini (2021), who demonstrated that substituting 50% pigeon pea flour in the traditional Balinese iwel cake contributed positively to its organoleptic quality. The product with pigeon pea substitution was categorized as good in all sensory parameters, with a color score of 2.90, taste score of 2.72, and texture score of 3.00. These results confirm that pigeon pea not only enhances nutritional quality but also maintains and even improves the sensory characteristics of food products, enabling them to remain well accepted by consumers. Based on this body of evidence, pigeon pea flour is considered highly potential as a raw material in the development of Supplementary Feeding (PMT) products, particularly due to its ability to enhance protein quality without compromising sensory acceptance. Therefore, its application in composite flour-based products, including flakes, represents a strategic opportunity to develop locally sourced, protein-rich supplementary feeding products that can contribute to improving children's nutritional intake. The nutritional composition of pigeon pea seeds per 100 g is presented in Table 1 below.

Table 1. Nutritional composition of pigeon peas

Component	Contents
Calories (Kcal)	336.00
Protein (g)	20.70
Fat (g)	1.40
Carbohydrate (g)	62.00
Calcium (mg)	12.50
Phosphorus (mg)	275.00
Iron (mg)	4.00
Vitamin A (mg)	250.00
Vitamin B1 (mg)	0.48
Vitamin C (mg)	5.00
Moisture(%)	12.20

(Parwata & Mariani, 2022)

1.4 Breadfruit

Breadfruit (*Artocarpus altilis*) is a valuable local source of carbohydrates, characterized by its relatively high starch content of approximately 20–30 percent. In addition to starch, breadfruit contains dietary fiber, vitamin C, potassium, and various bioactive compounds such as polyphenols and flavonoids, which contribute to antioxidant activity and potential health benefits. When processed into flour, breadfruit demonstrates good water and oil absorption capacity as well as favorable thermal stability, making it a versatile ingredient for various food applications. Its mild and neutral taste also facilitates its incorporation into composite food systems, thereby improving both nutritional quality and sensory characteristics. However, due to its low protein content and the absence of gluten, breadfruit flour requires combination with high-protein ingredients such as legumes to achieve a more nutritionally balanced formulation and to improve texture (Muhlishoh et al., 2021).

Several studies have consistently demonstrated the potential of breadfruit flour in food diversification and fortification. Gabriela (2021) reported that the addition of moringa leaf flour to breadfruit-based cookies enhanced nutritional value, providing approximately 499 kcal of energy and 8.8 g of protein per 100 g while maintaining acceptable sensory quality. Similarly, Ginting et al. (2020) showed that combinations of breadfruit flour with tempeh in biscuit formulations produced products containing 11.28 percent protein, 32.79 percent fat, and 45.63 percent carbohydrates, accompanied by favorable sensory attributes preferred by panelists. Breadfruit flour is therefore regarded as a healthy, energy-dense, and gluten-free base material with strong potential for development into supplementary feeding products for children. Its functional characteristics, ease of processing, and compatibility with nutrient-dense ingredients reinforce its relevance in the development of innovative, nutritionally balanced food products that support nutritional intervention efforts. The nutritional composition of breadfruit Flour per 100 g is presented in Table 2.

Table 2. Nutritional composition of breadfruit flour

Component	Contents
Calories (Kcal)	350.75
Protein (g)	5.16
Fat (g)	2.85
Carbohydrate (g)	77.09
Ash(%)	2.85
Moisture (%)	7.66
Dry matter (%)	87.87
Soluble fiber (g)	5.85
Crude fiber (9)	10.31
Insoluble fiber (g)	34.90

(Mehta et al., 2023)

1.5 Margarine

Margarine is a semi-solid emulsion consisting primarily of vegetable oils or fats and water, often enhanced with the addition of salt, colorants, and emulsifying agents to improve both taste and texture. Its standard composition typically includes around 80 percent vegetable fat, 16 percent water, and minor amounts of salt or other functional additives that may enhance taste, shelf life, or physical stability (Prasastono et al., 2022). The product is enriched with fat-soluble vitamins, including A, D, and E, and contains essential fatty acids such as omega-3 and omega-6, making it not only a culinary ingredient that enhances taste and mouthfeel, but also a source of nutrients that can contribute to human health when consumed in moderation.

From a physical and technological perspective, margarine is classified as a water-in-oil emulsion, where tiny water droplets are dispersed throughout a continuous fat phase. The structural stability of this emulsion is maintained by emulsifiers such as lecithin, monoglycerides, and diglycerides, which prevent the separation of water and fat, thereby ensuring a consistent texture and spreadability (Alfarizi et al., 2024). The semi-solid nature of margarine at room temperature makes it versatile for a wide range of applications, including baking, cooking, and as a direct spread. Its functional properties, such as creaming ability, aeration, and heat tolerance, are crucial for product formulation in both home and industrial food processing, contributing to texture, volume, and sensory attributes of the final products. The combination of nutrient content and functional performance underscores margarine's importance as a key ingredient in modern food production.

1.6 Skim milk

Skim milk is a type of milk from which the majority of the fat content has been removed, resulting in a product that contains lower levels of calories and fat compared to whole milk, while still retaining essential nutrients such as carbohydrates and proteins that are important sources of energy and contribute to the maintenance and development of body tissues (Trisdayanti & Putra, 2021). The reduction in fat content makes skim milk particularly suitable for individuals who are following a low-calorie diet, those aiming to reduce saturated fat intake for cardiovascular health, or people who require controlled energy intake without compromising protein consumption. In addition to its nutritional profile, skim milk exhibits functional properties that are valuable in both culinary and industrial applications. Its white color results from the minimal presence of fat-soluble pigments, including carotene and riboflavin, distinguishing it from whole milk, which has a naturally yellowish hue due to higher fat content (Pamela, 2022). Skim milk can be easily incorporated into a variety of food products, including baked goods, dairy-based beverages, and powdered formulations, without significantly altering texture or taste. Its protein content supports muscle maintenance and growth, while its lactose and mineral composition contribute to energy provision and electrolyte balance. The combination of low fat, moderate calorie content, and preserved nutritional value makes skim milk a versatile ingredient for health-conscious consumers and functional food formulations.

1.7 Sugar

Sugar is one of the most widely used sweeteners in both foods and beverages, primarily obtained from sugarcane through a series of extraction, clarification, and purification processes that result in the formation of crystalline sugar, which may appear white or slightly yellow depending on the degree of refinement (Huda & Falah, 2025). The extraction process involves crushing the sugarcane to obtain juice, followed by filtration, evaporation, and crystallization to separate the sugar crystals from the molasses and other impurities. In 100 grams of granulated sugar, there are approximately 364 kilocalories and 94 grams of carbohydrates, making it a concentrated source of energy, while the glycemic index of around 58 classifies it as a medium-GI carbohydrate (Aprilia et al., 2022). Beyond its role in providing sweetness, sugar contributes to multiple functional properties in food systems. It acts as a stabilizer by helping maintain the structural integrity of certain products, and it can serve as a natural preservative by lowering water activity and thereby inhibiting microbial growth. Sugar also plays a critical role in developing desirable textures, such as tenderness and chewiness, in baked goods and confectioneries. Furthermore, it contributes to color formation through caramelization, a chemical reaction that occurs when sugar is exposed to heat, producing characteristic brown hues and complex taste compounds. The multifunctional nature of sugar makes it an indispensable ingredient in a wide variety of culinary and industrial applications.

2. Methods

2.1 Material and tools

The materials used in this study included pigeon pea (*undis*) obtained from Nuansa Dewata Supermarket, breadfruit flour (*Lingkar Organik*), margarine (*Blueband*), skim milk powder (*Subur Kimia Jaya*), vanili (*Koepoe-Koepoe*), powdered sugar, salt, Kellogg's corn flakes (commercial), phenolphthalein indicator, Kjeldahl tablets, distilled water, boric acid, NaOH, and H_2SO_4. The tools used in this study included bowls, spoons, spatulas, stirrers, pans, baking trays, knives, sieves, plastic containers, plastic cups, porcelain crucibles, aluminum dishes, tweezers, burettes, drop pipettes, and volumetric pipettes. The study also used a gas stove (*Rinnai*), oven (*Kirin*), digital scale (*Fuji*), drying oven (*Glotech*), desiccator, analytical balance (Pioneer), furnace (Wisetherm), texture analyzer, Erlenmeyer flask (Pyrex), beaker (Pyrex), measuring cylinder (Pyrex), distillator, muffle furnace, and plastic funnel.

2.2 Experimental design

This experiment used a Completely Randomized Design/*Rancangan Acak Lengkap* (RAL) consisting of five treatment levels made from different ratios of pigeon pea flour and breadfruit flour. All treatments were arranged randomly and replicated to obtain consistent and reliable experimental data. After the formulation and initial evaluations were completed, the best-performing treatment was selected and compared with a commercial flakes product as the control. Both samples were then analyzed according to the observed parameters to identify differences in nutritional quality and sensory characteristics between the locally developed formulation and the commercial product.

2.3 Sample preparation

2.3.1 Making pigeon pea flour

The process of producing pigeon pea flour in this experiment followed the procedure described by Adedokun et al. (2024), with slight modifications to optimize flour quality and suitability for food product development. The first step involved thoroughly washing the pigeon peas under clean running water to remove dirt, dust, and any surface impurities. After washing, the pigeon peas were soaked in water for 1 hour to soften the seeds, which also helps reduce cooking time and facilitates easier removal of seed coats. This soaking step additionally contributes to the reduction of certain anti-nutritional factors naturally present in pigeon peas, such as tannins and phytates, which can interfere with nutrient absorption.

Following the soaking stage, the pigeon peas were boiled for 20 minutes to further soften the seeds and facilitate the peeling process. The seed coats were carefully removed by hand until all outer layers were completely clean, as the presence of seed coats could negatively affect the texture and color of the final flour. The peeled pigeon peas were then dried using a food dehydrator set at 60°C for 24 hours. This controlled drying process ensured that the moisture content was sufficiently reduced, minimizing the risk of microbial growth and extending the shelf life of the flour. Once completely dried, the pigeon peas were ground into a fine powder using a high-speed blender. The resulting flour was sieved through an 80 mesh sieve to obtain a uniform, fine-textured pigeon pea flour suitable for incorporation into various food formulations, ensuring consistency in texture and functionality for further applications in product development.

2.3.2 Making sundish flakes

The process of making flakes in this experiment was adapted from the method described by Pratiwi et al. (2025) with several modifications to optimize texture, taste, and nutritional quality. The procedure began by sifting the flour to remove any lumps or impurities, ensuring a smooth and uniform base for the dough. This step is essential for achieving a consistent texture in the final flakes and preventing uneven baking. Once sifted, the flour was weighed according to the predetermined treatment ratios and placed into a mixing bowl. Sugar, skim milk, salt, and vanilla were gradually added to the flour, and the mixture was stirred thoroughly until all ingredients were evenly distributed, forming a dry blend with uniform consistency.

Table 3. Comparison of flakes formulations

Ingredient Composition (grams)	Formulation				
	P1	P2	P3	P4	P5
Pigeon pea flour	15	30	45	60	75
Breadfruit flour	85	70	55	40	25
Mineral Water	40	40	40	40	40
Margarine	20	20	20	20	20
Skim milk powder	8	8	8	8	8
Powdered sugar	30	30	30	30	30
Vanili	1	1	1	1	1
Salt	1	1	1	1	1

(Pratiwi et al., 2025)

The formulations used in this study consisted of five treatment combinations of breadfruit flour and pigeon pea flour. Treatment P1 contained 85 g of breadfruit flour and 15 g of pigeon pea flour, while P2 consisted of 70 g of breadfruit flour and 30 g of pigeon pea flour. Treatment P3 was formulated using 55 g of breadfruit flour and 45 g of pigeon pea flour. Furthermore, P4 contained 40 g of breadfruit flour and 60 g of pigeon pea flour, whereas P5 consisted of 25 g of breadfruit flour and 75 g of pigeon pea flour.

Following this, water and melted margarine were gradually incorporated into the mixture while stirring continuously. This careful incorporation ensured that the dough achieved a homogeneous consistency without clumps or pockets of unmixed ingredients. The resulting dough was then transferred onto a baking tray that had been lined with baking paper to prevent sticking. Using a spatula or roller, the dough was evenly flattened into a uniform sheet to ensure even baking. The flattened dough sheet was baked in a preheated oven at 150°C for 20 minutes, which allowed the dough to set and partially dry while maintaining the desired crispiness. After baking, the sheet was removed from the oven and allowed to cool to room temperature, a crucial step to prevent condensation and moisture retention that could affect the texture of the flakes. Once cooled, the sheet was ready for further handling, such as cutting or breaking into smaller flakes according to the intended final product size. The complete flakes formulation for each treatment group can be seen in Table 3, providing detailed ratios of each ingredient used in the preparation.

2.4 Analysis procedures

This study conducted several analyses, including sensory assessments for color, texture, aroma, taste, and overall acceptability, as well as flake characteristics using a texture analyzer and colorimeter. The best results were then followed up with protein content testing using the Kjeldahl method, water content testing using the gravimetric method, and ash content testing using the gravimetric method.

2.4.1 Hedonic test

Testing of the sensory properties of SunDish Flakes was carried out by hedonic tests. A hedonic test was carried out to determine the level of consumer preference for the SunDish flakes formulation created including color, aroma, taste and overall acceptance. The panelists used in the test were 25 semi-trained panelists from students from the Faculty of Agricultural Technology, Udayana University who had taken sensory evaluation courses. Samples were presented on randomly coded plastic plates to ensure panellists did not see all samples. The sample presented was pre-prepared flakes. The panelists were asked to provide an assessment of the level of liking according to predetermined criteria and the results obtained were expressed on a numerical scale from 1 to 5 with a rating of 5 = very similar, 4 = like, 3 = neutral, 2 = dislike, and 1 = very dislike.

2.4.2 Hardness and color analysis

Hardness analyzing uses a texture analyzer, a tool used to analyze the mechanical properties of a material. This test aims to determine whether the addition of certain treatments affects the hardness of the flake texture. Color analyzing uses a colorimeter, a tool used to analyze color intensity using L*, a*, and b* values. Place the sample on a white surface, open the colorimeter application until the camera display is visible, then point the camera vertically at the sample with the flash on. Once the camera and sample are positioned correctly, press the button to take a picture to take the L*, a*, and b* readings. Then, record the resulting color readings.

2.4.3 Moisture, ash, and protein content analysis

The moisture content of the flakes was determined using the gravimetric method. The dish was heated in an oven for 30 minutes, then cooled in a desiccator. The dish was weighed until it reached a constant weight. Place 2 grams of sample in the dish and dry it in an oven for 4 hours at 105°C. Afterward, cool it in a desiccator for 15 minutes, then weigh it and record the weight. The sample was then dried for 30 minutes, cooled in a desiccator for 15 minutes, and then weighed again. This process was repeated until a constant weight

(±0.02 grams) was achieved. The moisture content was then calculated using the following formula:

$$\text{Moisture content (\%)} = \frac{(a-b)}{a} \text{ x } 100\% \qquad \text{(Eq. 1)}$$

Where, a represents the initial sample weight (g), while b represents the final sample weight (g). The ash content of the flakes was tested using the gravimetric method. The dish was dried in an oven for 1 hour at 105°C, then cooled in a desiccator for 15 minutes, and then weighed to obtain W1. Afterward, 2 grams of the ground sample (W) was placed in the dish. The sample was heated over a heater until it charred and smokeless, then fired in a muffle furnace for 5 hours at 550°C. After the charring stage, the dish was cooled, placed in a desiccator for 15 minutes, and then weighed to obtain the final weight (W2). The ash content was calculated using the following formula:

$$\text{Ash content (\%)} = \frac{W2 - W1}{W - W1} \text{ x } 100\% \qquad \text{(Eq. 2)}$$

A 0.1 g sample was added with a 0.5 g Kjeldahl tablet, then 5 ml of 97% H2SO4 was added and digested for 2 hours or until the color was clear. Then, 25 ml of distilled water was added, poured into a Kjeldahl flask, and 3 drops of PP indicator and 25 ml of 50% NaOH were added. Distillation was then carried out for 4 minutes. Fill the distillate container with 10 ml of 3% boric acid and distillate to a volume of 80 ml. The distillate was titrated with HCl until it turned pink. The percentage protein was calculated using the following formula:

$$\text{Protein content (\%)} = \frac{(Vol\ HCl - vol\ blanko)\ x\ NHCl\ x\ 14{,}007\ x\ 6{,}25\ x\ 100\%}{mg\ sample} \qquad \text{(Eq. 3)}$$

2.5 Data analyzed

The data obtained from the organoleptic test will be statistically analyzed using Analysis of Variance (ANOVA). If a significant effect among treatments is observed, the analysis will be continued using the Duncan New Multiple Range Test (DNMRT) at a significance level of α = 5%, processed with IBM SPSS Statistics 27. The best treatment based on the organoleptic results will then be subjected to protein content, moisture content, ash content, fat content, and hardness analyses, which will be evaluated using an Independent t-test in Minitab.

3. Results and Discussion

3.1 Sundish flakes hedonic test results

The sensory test results based on the level of preference (Hedonic Test) for color, texture, aroma, taste, and overall acceptance are presented in a spider web diagram in Fig 1. The hedonic evaluation results (Figure 1) showed that treatment F4 (60% pigeon pea flour and 40% breadfruit flour) received the highest scores across all sensory attributes, namely color (3.92), texture (4.40), taste (4.08), and overall acceptability (4.24). This formulation was identified as the one most preferred by the panelists. The appealing color appearance was produced by anthocyanin pigments in pigeon pea flour, which contribute to a reddish-brown tone, and carotenoid compounds in breadfruit flour that help maintain a bright and stable color, resulting in a product that is neither too dark nor too pale (Suriani et al., 2021). The proportion between pigeon pea flour and breadfruit flour clearly influenced the final color of the flakes. Increasing the proportion of pigeon pea flour enhanced color intensity and improved visual attractiveness, although excessively high proportions may result in overly dark products and reduced preference. Color development in cereal and legume mixtures is closely associated with the Maillard reaction, a nonenzymatic reaction between reducing sugars and amino groups during heating that produces melanoidin pigments and determines final visual characteristics (Qi et al., 2025).

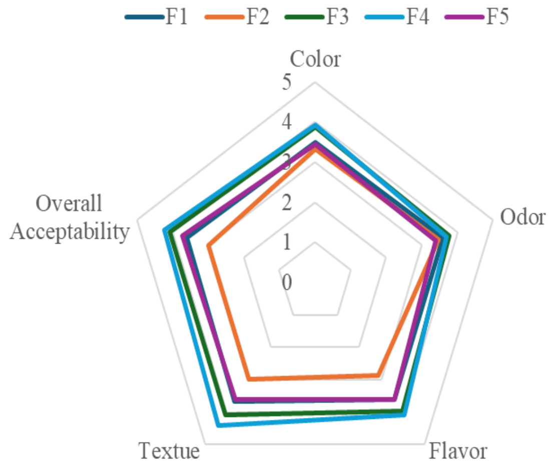

Fig. 1. Spider web hedonic test results of sundish flakes

The aroma attribute indicated that no significant differences in liking were observed among treatments. Neutral to favorable responses showed that all formulations remained within an acceptable sensory range. Heat treatment at 110–230 °C played a role in reducing volatile compounds responsible for off- taste through the inactivation of lipoxygenase, thereby lowering lipid oxidation and the formation of unpleasant odors (Ponskhe et al., 2025). In cereal and legume-based products, changes in ingredient composition do not always lead to distinct sensory differences because volatile compounds may undergo masking, interaction, or modification during thermal processing. This agrees with Saffarionpour et al. (2024), who stated that interactions between volatile compounds, protein components, and heat can alter taste perception and suppress off- taste, meaning that variations in ingredient proportions are not always perceived as significant sensory differences.

The texture attribute showed a significant influence from the proportion of flour used. Formulation F4 was rated as having the most desirable texture, as the 60% pigeon pea flour content contributed to the formation of a crisper structure that was considered most appropriate for flake products. This characteristic is related to the relatively high protein and dietary fiber content of pigeon pea, which forms a firm but brittle matrix after heating, producing flakes that break easily and give a pleasant crisp sensation when chewed. These findings are consistent with Pasqualone et al. (2020), who reported that the incorporation of legume flour with higher protein content can improve crispness through the formation of porous microstructures and reduced water retention in cereal-based products.

Overall acceptability, which represents the integration of all sensory attributes, showed that the formulation containing 60% pigeon pea flour and 40% breadfruit flour achieved the highest score. A crisp texture and uniform golden-brown color were key factors influencing consumer acceptance, especially when taste remained within a relatively similar preference range among formulations. This result is in line with Szakaly et al. (2023), who emphasized that crispness and fracture characteristics are major drivers of consumer acceptance in cereal-based food products. The sensory evaluation of formulation F4 also illustrates promising potential for acceptance under real consumption conditions, particularly among children, where consistent color, pleasant crispness, and the absence of undesirable odors are important factors that encourage repeated intake. This formulation not only demonstrates a high level of liking among panelists but is also strongly relevant in the context of nutritional interventions, as it offers better nutritional value through legumes as a protein source and breadfruit as an energy source while remaining organoleptically acceptable. These characteristics increase the likelihood of consistent consumption and support the effectiveness of supplementary feeding programs, in which nutritional adequacy and sensory acceptance are two key aspects that jointly determine the success of intervention efforts.

Table 4. Color test results using a colorimeter

Formulation	Color Names	L*	a*	b*
F1	Sandrift Brown	58.03±1.02[a]	3.70±0.85[ab]	15.27±0.95[a]
F2	Brandy Rose	57.63±0.70[a]	3.23±0.35[ab]	15.30±0.95[a]
F3	Light Wood	53.60±0.88[b]	4.47±0.77[ab]	14.17±0.66[a]
F4	Light Wood	52.80±0.45[b]	3.03±0.64[b]	16.30±1.57[a]
F5	Potters Clay	50.10±1.21[c]	4.60±1.05[a]	16.57±0.11[a]

The results of color analysing using a colorimeter (Table 4) show that F1 produced the color Sandrift Brown, F2 Brandy Rose, F3 and F4 both produced the color light wood, while F4 produced the color potters clay. The colors produced on the flakes with various formulation treatments can be seen in (Fig. 2). Based on the brightness level observed from the L* value, significant changes were found among treatments. The decreasing brightness value (L*) indicates that the flake products produced a progressively darker color with the increasing use of gude bean flour. This can be caused by more intense Maillard or caramelization reactions during the roasting process due to the higher protein and reducing sugar content in gude beans, which triggers non-enzymatic browning reactions, where proteins (as a source of amino acids) and reducing sugars react at high temperatures (roasting 150°C) to form dark brown melanoidin pigments (Calista et al., 2022) which instrumentally reduce the L* value in CIELAB measurements.

Fig. 2. Flakes results with various treatments

The a* value parameter (Table 4) which indicates the intensity of the reddish-greenish color, resulted in an increase in the value from F1 by 3.70 to 4.60 in F5, with significantly different results for each treatment. Positive results in the a* values indicate that the resulting flakes tend to be reddish in color. The highest a* value in F5 indicates a color that tends to be redder than other formulations. This indicates that the addition of pigeon pea also increases the reddish color of the flakes due to the presence of anthocyanin and flavonoid compounds as the main pigments in pigeon peas (Roosmarinto et al., 2016).

Based on the b* value which indicates a yellowish to bluish color, the analysis results did not show a significant difference between treatments, the b* value in F1 produced a value of 15.27, F2 15.30, F3 14.17, F4 16.30 and F5 of 16.57. All treatments produced a positive b indicating that the resulting flakes color tends more towards yellowish to brown than towards blue. However, it can be seen that there was an increase in the b value in each treatment due to the addition of pigeon pea flour used. The results that were not significantly different (P>0.05) in this b* value indicate that the ratio of pigeon pea bean flour and breadfruit flour does not affect the color change of the flakes in the yellow-blue range, as pigeon pea bean flour produces a more reddish-brown color.

Overall based on the L*, a*, and b* values that have been tested on flakes, the F4 formulation, which is 60% pigeon pea flour and 40% breadfruit flour, produces an optimum point based on the resulting color balance with an L* value of 52.80 ± 0.45 (fairly light), a* = 3.03 ± 0.64 (medium red), and b* = 16.30 ± 1.57 (fairly high yellow). Formulation 4 produces an attractive flake appearance, not too dark, but still has the natural brown character expected from flakes products, so that the Light Wood type color is produced on the flakes which is most preferred by panelists in the results of the hedonic test that has been carried out (Fig 1.).

Table 5. Texture test results using texture analyzer

Formulation	Hardness (N)
F1	12.78±2.64a
F2	12.82±0.84a
F3	9.93±1.12ab
F4	8.51±2.19bc
F5	5.59±1.77c

The highest hedonic texture score in F4 also aligns with the texture analyzer results (Table 5), with a hardness level of 8.51±2.19 N, consistent with the expected characteristics of crispy, moderately hard flakes. The higher starch content in breadfruit flour and the protein content in pigeon pea flour contribute to the formation of a flaky and brittle texture after baking. Meanwhile, the highest aroma score was found in F3 (3.76), which is likely due to the balance between the aromas of pigeon pea flour and breadfruit flour produced in the P3 formulation.

3.2 Sundish chemical characteristics test results for sundish flakes F4 and commercial

The results of the chemical characteristics test for Sundish Flakes F4 and Commercial can be seen in Table 6.

Table 6. Chemical characteristics test results of sundish flakes F4 and commercial

Sample	Ash Content (%)	Moisture Content (%bb)	Protein (%)
Commercial	1,213±0.351^{b}	4.88±0.075^{b}	7,173±.,420^{b}
Best Formulation (F4)	2,383±0.047^{a}	5.27±0.066^{a}	10,543±0.185^{a}

3.2.1 Moisture content

The analysis results show a significant difference (P < 0.05) in moisture content between commercial flakes and Sundish Flakes. Commercial flakes have a moisture content of 4.88%, while Sundish Flakes have a higher moisture content of 5.27%. Moisture content is an important parameter in dried food products because it affects shelf life, texture, and microbiological stability. The lower moisture content in commercial flakes is thought to be related to the use of corn flour as the main ingredient, which has a high starch content and allows for optimal moisture release during baking, resulting in a crispier texture (Ayu et al., 2021). Conversely, the higher moisture content in Sundish Flakes is due to the use of pigeon pea flour and breadfruit flour as its constituents.

Undis beans have a relatively high initial moisture content (16.1% in dry form) and are rich in protein. Protein is hydrophilic because it contains polar groups that can bind water molecules, thus increasing the product's moisture content (Hapsari et al., 2022). This aligns with the findings of Pratiwi et al. (2025), who showed that the average moisture content of flakes made from arrowroot tubers and pigeon pea ranged from 4.91–5.18%. Increasing the proportion of pigeon pea flour tended to increase the moisture content, although not statistically significantly. This mechanism occurs because during roasting, the protein undergoes denaturation and coagulation, resulting in more water retention. The carboxyl groups in protein are also hydrophilic, so the higher the protein content, the more water can be absorbed and retained.

Additionally, breadfruit flour also contributes to the moisture content of Sundish Flakes due to its high crude fiber content (Noviasari et al., 2023). Coarse fiber acts like a sponge, absorbing and retaining water for longer (Gionte et al., 2022). This explains the higher moisture content of Sundish Flakes, even after roasting. According to SNI 01-4270 1996, the maximum moisture content for cereal flakes is 3%. The moisture content of both products exceeds this threshold and therefore does not meet national quality standards. This indicates the need to optimize the ingredient formulation or roasting process to reduce the moisture content.

3.2.2 Ash content

From the results of the chemical analysis in Table 6 it shows a significant difference ($P<0.05$) between the ash content of commercial flakes and Sundish flakes. Commercial flakes containing 90% corn flour produced an ash content of 1,213% while Sundish flakes with Formula 4, namely a ratio of 40% pigeon flour and 60% Breadfruit flour, produced a higher ash content of 2,383%. This significant difference indicates that different types and compositions of raw materials will affect the ash content of the product. Ash content is the organic residue remaining after the combustion of organic materials, which indicates the total mineral content of a food, including calcium, phosphorus, magnesium, and potassium (Titonia et al., 2025). In addition, ash content is also used as a parameter of food quality and purity.

The higher ash content in Sundish flakes is related to the characteristics of the ingredients. Where pigeon peas have a higher mineral content than corn, so their use in the formulation increases the ash content significantly. Breadfruit flour also contributes to the ash content, although its contribution is lower than that of pigeon pea flour. These results are in line with the research of Pratiwi et al. (2025) who reported that the ash content in flakes increases with the increase in the proportion of pigeon pea flour and the decrease in other ingredients with lower mineral content, such as arrowroot tubers. The higher mineral content in pigeon peas has been shown to improve the chemical composition of the product. According to the Indonesian National Standard (SNI 01-4270-1996), the maximum ash content permitted in cereal flakes is 4%. Ash content in flakes Commercially available cereals and Sundish flakes fall below this threshold, thus meeting the established quality standards. However, the higher ash content of Sundish Flakes also indicates its potential as a better source of minerals, particularly calcium, phosphorus, and other essential minerals that play a role in children's growth and bone health.

3.2.3 Protein content

Based on the data in Table 6, an analysis of the protein content of two types of flakes was performed: commercial flakes based on 90% corn flour and Sundish Flakes formulated from a mixture of pigeon pea and breadfruit flours. The test results showed that the protein content of the commercial flakes was 7.173%, while that of Sundish Flakes reached 10.543%. Statistically, the protein content of these results showed a significant difference ($P < 0.05$). This demonstrates the effectiveness of the SunDish formulation in improving the protein profile of the resulting flakes. Both commercial flakes and Sundish Flakes exceeded the minimum protein content standard set by SNI 01-4270-1996, which is 5%, confirming that these formulated products have good protein quality. The increase in protein in Sundish Flakes was primarily influenced by the use of pigeon pea flour. This is in line with research by Pratiwi et al. (2025), which showed that the protein content of flakes increased significantly with increasing proportions of pigeon pea flour and decreasing proportions of breadfruit. The high protein content of pigeon pea makes them a potential source of vegetable protein to improve the nutritional quality of food products.

The relevance of increasing the protein content of Sundish Flakes becomes important when it is linked to children's protein adequacy. Based on the Indonesian Nutritional Adequacy Intake, the daily protein requirement for children aged 1–3 years is approximately 20 grams, while for children aged 4–6 years, it is approximately 25 grams (Ministry of Health, 2023). With a protein content of 10.543%, Sundish Flakes has the potential to be a supplementary feeding (PMT) product option to help meet children's protein needs. Hartini et al. (2023) confirmed that providing supplementary feeding based on local foods enriched with protein has been proven to improve the nutritional status of early childhood and reduce the prevalence of stunting. Therefore, SunDish Flakes not only serves as a locally based cereal alternative but also has practical potential in nutrition intervention programs, particularly in supporting toddler protein intake to prevent stunting.

3.3 Economic feasibility analysis and comparison with commercial products

The results of raw material cost, production cost breakdown, selling price simulation, and break even point (BEP) analysis of SunDish flakes are presented in Table 7, Table 8, Table 9 and Table 10. Based on the production cost analysis results in Table 7, the total cost of raw materials used to produce one serving of 60g flakes is IDR 2,852, and the Cost of Production for 60g SunDish flakes per package in Table 8 is IDR 4,712.

Table 7. Raw material cost of breadfruit–pigeon pea flakes

Ingredient	Quantity per batch	Cost per batch (IDR)	Cost per 60 g unit (IDR)
Pigeon pea	60 g	3,600	1,200
Breadfruit flour	40	1,400	467
Granulated sugar	40 g	940	313
Margarine	28 g	2,030	677
Skim milk powder	6 g	348	116
Salt	1 g	21	7
Vanilla essence	1 ml	175	58
Water	40 ml	42	14
Total	—	8,556	2,852

Table 8. Production cost breakdown of breadfruit–pigeon pea flakes (60 g per unit)

Cost Component	Cost (IDR/unit)
Raw materials	2,852
Energy (electricity and gas)	160
Labor	400
Packaging (resealable stand-up pouch)	1,300
Total Cost of Goods Manufactured (HPP)	4,712

The selling prices presented in Table 9 show that, with a profit margin of 30–50%, the selling price of breadfruit and pigeon peas ranges from IDR 6,100 to IDR 7,100 per unit. This price is lower than the retail price, which is approximately IDR 14,900 per unit of the same size. This price difference reflects the fair value of locally produced food and also opens up opportunities for use as supplementary food (SNF), which requires a competitive price while maintaining nutritional value.

Table 9. Selling price simulation based on profit margin

Profit Margin	Selling Price (IDR/Unit)
30%	6.100
40%	6.600
50%	7.100

Furthermore, the break-even point (BEP) calculations in Table 10 show that with a selling price of IDR 6,500 to IDR 7,000 per unit, break-even can be achieved with a sales volume of 437 to 558 units per month. This BEP is considered suitable for small businesses or community projects. Compared to commercial products priced at USD 14,900, which are often produced using expensive and complex distribution processes, breadfruit and pigeon pea flour offer the potential for improved production and storage at higher temperatures. Overall, the analysis presented in Tables 7-10 shows that breadfruit and pigeon pea flour are not only cost-effective but also have a positive impact on the cost of the USD 14,900 product, particularly in terms of value and the potential for improved food quality through the use of local ingredients.

Table 10. Break-Even Point (BEP) Analysis

Selling Price (IDR)	BEP (units/month)
6.000	778
6.500	558
7.000	437

4. Conclusions

The conclusion of the research is that SunDish Flakes, made from pigeon pea flour and breadfruit flour using the best 60:40 formula, demonstrated excellent sensory characteristics, with a texture score of 4.40 (preferred), a taste score of 4.08 (preferred), and an overall acceptability score of 4.24 (preferred). Chemical analysis revealed a protein content of 10.543%, an ash content of 2.38%, and a moisture content of 5.27%, with a higher protein content compared to commercial flakes products on the market, which have a protein content of 7.173%. The results indicate that SunDish Flakes have the potential to be a nutritious, practical, and relevant local food-based supplementary food to support sustainable stunting prevention programs and food security in Indonesia.

Based on the results of the study, the authors suggest that validity and acceptability tests in the target age group should be carried out in various environments to ensure broad acceptability, Before mass production, these products must undergo testing shelf life to ensure that their physical and nutritional characteristics remain maintained during storage, and Collaboration with SMEs or local food producers is recommended to accelerate and scale up food production.

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Author Contribution

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During the preparation of this work, the authors used Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. 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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