



Nutraceutical Innovation of Cereal form Japanese Papaya Leaves and Honey Based on Local Wisdom of the Baduy Tribe

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ABSTRACT

Stunting remains a significant public health problem in Indonesia, especially in indigenous communities such as the Baduy tribe. Intervention through functional food innovations based on local natural ingredients are considered strategic. This study aims to develop nutraceutical cereal preparations from Japanese papaya leaves (*Cnidioscolus aconitifolius*) and honey as a stunting prevention and immunomodulator. This experimental study consisted of the formulation and evaluation stages of three cereal formulas (F1, F2, F3) containing varying concentrations of Japanese papaya leaves (10%, 15%, 20%) and honey. The evaluation included granule characteristics (organoleptic, particle size, compressibility index, water content, granule flow), cereal characteristics after reconstitution (pH, viscosity, sedimentation, microbiology), proximate tests, heavy metals, nutritional adequacy, and hedonic tests by Baduy children. The results of this study showed that Formula 2 showed the best physical characteristics with a compressibility index of 7% and optimal flow rate. Formula 1 excelled in protein content (21.57 g/100 g) and viscosity, while Formula 2 received the highest score in the hedonic test (most preferred response). All formulas met SNI and BPOM standards for microbiological safety and heavy metals. Formulas 1 and 2 met BPOM criteria as a food source of protein ($\geq 10\%$ RDA). The conclusion of this study is that the combination of Japanese papaya leaves and honey in the form of granular cereal is worthy of being developed as a functional food for stunting prevention and a natural immunomodulator for children, especially in traditional communities such as the Baduy tribe.

Keywords: Japanese Papaya Leaves; Honey; Nutraceutical Cereals; Stunting; Baduy tribe

INTRODUCTION

Stunting is a serious health problem in the world and Indonesia¹. According to the WHO, in 2022, there were 148.1 million children under 5 years old who experienced stunting. Indonesia ranks second in Southeast Asia with a high prevalence.² Data from the 2023 Indonesian Health Survey (SKI) shows that the prevalence of stunting in Indonesia reached 21.5%, with Banten Province

experiencing an increase to 24%. In Banten, there were 21,171 children with malnutrition as of December 2023. Based on e-PPGBM data, Kanekes Village in Leuwidamar District, Lebak Regency, Banten Province recorded the highest prevalence at 11.20%, where the village is inhabited by the Baduy tribe.³ The government's target of reducing stunting rates to 14% by 2024 is still far from expectations⁴.

The Indonesian Ministry of Health is carrying out specific nutritional interventions to prevent stunting, focusing on direct causes such as malnutrition and infectious diseases.¹ One potential natural ingredient is Japanese papaya leaves (*Cnidocolus aconitifolius*), known as a superfood because they are high in protein, vitamins, calcium, iron, and phytonutrients that can kill protozoa. They also have nutraceutical potential due to their benefits in various pharmacological activities.^{5,6} In 100 grams of Japanese papaya leaves contain 5.8% protein, 1.9% crude fiber, 199.4 mg calcium (Ca), 217.2 mg potassium (K), 11.4 mg iron (Fe), 164.7% vitamin C and 0.085 mg carotene.^{5,6} Sari's research (2024) stated that Japanese papaya leaves have antioxidant activity.⁷ Research by Imawati et al. in 2023 stated that Japanese papaya leaves also have antibacterial activity against *Staphylococcus aureus*.⁸ Japanese papaya leaves grow easily in Indonesia and are often processed as vegetables.⁹

Another natural ingredients which has potential to prevent stunting is Honey due to its immunomodulatory and antibacterial properties. Studies demonstrate that honey's immunomodulatory mechanism enhances lymphocyte number and proliferation in experimental mice, thereby potentially strengthening the overall immune response. Regular honey consumption may help protect against infection that contribute to chronic malnutrition underlying stunting. Cereal, a convenient, ready-to-eat food, also plays a role in improving community nutrition. Combining local foods such as Japanese papaya leaves, honey, and cereal can effectively support stunting prevention efforts.¹⁰⁻¹²

Research on nutraceuticals related to stunting has been conducted. For instance, a study by Sofia et al. (2023) entitled "Nutraceutical Jelly Drink Combination of Moringa Leaf Extract and Curcuma Rhizome as Anti-Stunting Agent in Vivo" reported that administration of the jelly drink at a dose of 1000 mg/day significantly increased fetal body weight

and length ($p < 0.05$).¹³ Furthermore a review by Rahmah et al. (2023) identified 12 studies involving various dosage forms of natural product-based preparations, with *Moringa oleifera* leaves and *Curcuma* rhizomes being the most commonly used ingredients in efforts related to stunting prevention.¹⁴ Research on honey has been conducted by Nur Hasanah et al., entitled "Formulation of a Nutraceutical Beverage Containing Ginger, Lime, and Honey to Enhance Immune Function".¹⁵ However, these studies have not yet contributed to a significant reduction in stunting prevalence, as the stunting rate in Indonesia remains far from the national target of 14% by 2024.¹

The novelty of this study is in the development of a nutraceutical product derived from natural ingredients, specifically the combination of Japanese papaya leaves and honey in the form of cereal. This formulation is intended as a functional food with potential to support nutritional improvement. The cereal dosage form offers advantages in terms of convenience and practicality, and may contribute to optimizing community nutritional intake.¹⁶

This study aims to obtain a formula for a nutraceutical preparation of papaya leaf and honey cereal that has the best physical and chemical characteristics and is preferred by Baduy children.

METHODS

This research consists of two stages, namely the preparation and verification stage of raw materials and the formulation and evaluation stage of the preparation.

Material

The materials used in this study were Japanese papaya leaves (*Cnidocolus aconitifolius*) obtained from Bogor, honey powder, arrowroot flour (PT. Agro Indah Permata), xanthan gum (Neimenggu Fufeng Biotechnologies, Co. Ltd, China), sodium benzoate (Emerald Kaisma Chemical, Indonesia), sucrose (Haihang Industry Co. Ltd, China), strawberry flavor

powder, melon flavor powder, vegetable creamer (PT. Sari Indofood Corporation, Indonesia), soy milk powder (Unisoyn, Singapore), and distilled water.

Tools

The tools used in this study include analytical scales JL-602 (Mettler Toledo), blender type MX-GX2062WSR (Panasonic), mixer EHSM 3417 (Electrolux), oven UFE600 (Mettler), a set of sieve and vibrator (Retsch D-42759 HAAN), tapped density tester (Pharma Test D-63512 Hainburg), moisture content tester OHAUS MC MB45 (Mettler Toledo), standard funnel, stopwatch, stand, viscometer Stormer Serial 80202 (Arthur H Thomas. Co Philadelphia USA), viscometer VT-04 (Rion), pH meter LAQUA-PH1100 (Horiba Scientific).

Ways of working

Making Japanese papaya leaf and honey cereal consists of several stages, namely:

Sample preparation

Prepare the Japanese papaya leaves and honey powder, then weigh them separately.

Making Japanese papaya leaf flour.

Japanese papaya leaves (*Cnidioscolus aconitifolius*) obtained from Bogor were sorted to separate fresh leaves from dried leaves. The leaf blades were then separated from the leaf stalks. The leaves were then washed with running water to remove dirt, and the final stage of washing was rinsing with pure water. The washed Japanese papaya leaves were boiled for 15 minutes, then dried in an oven at a temperature of (40 ° C) and turned over until the moisture content reached <10%. The dried papaya leaves were then reduced in particle size using a crusher (dry blender) to form a powder. The papaya leaf powder was then sieved with a 100 mesh sieve. The powder was then stored in a sealed, airtight container.

Japanese papaya leaf and Honey cereal formulation

Table 1. The nutraceutical Formula of Japanese Papaya Leaf Cereal Granules and Honey

No	Material	Function	Formula (%b/b)		
			F1	F2	F3
1	Japanese Papaya Leaves	Active Ingredients	10	15	20
2	Honey Powder	Active Ingredients	7	7	7
3	Arrowroot Flour	Thickener	20	20	20
4	Xanthan Gum	Suspension	1	1	1
5	Sodium Benzoate	Preservative	0.1	0.1	0.1
6	Sucrose	Sweetener	13	13	13
7	Egg	Binder	20	20	20
8	Vanilla essence	Taste	5	5	5
9	Vegetable Creamer	Taste	5	5	5
10	Soy Protein Isolate	Filler	18.9	13.9	8.9

Formulation of Japanese papaya leaf and honey cereal. Japanese papaya leaf cereal granules consist of several components listed in table 1. Each ingredient such as Japanese papaya leaf flour, honey powder, arrowroot flour, xanthan gum, sucrose, vegetable creamer, sodium benzoate and soy milk is weighed then mixed until homogeneous using a mixer for 10 minutes, eggs are added according to the amount contained in the formula until a granule mass is formed. The formed granule mass is then sieved with a sieve no. mesh 10, then dried using an oven at a temperature of 50 0 C for 3 hours until a granule moisture content of 2-4% is obtained. The sieved dry granules are then continued for evaluation of granule characteristics.

Evaluation of Cereal Preparations

Organoleptic Test

Organoleptic testing is carried out by observing and assessing the shape, aroma, taste and color of cereal granules (17,36).

Evaluation of Particle Size Distribution

A total of 100 grams of papaya leaf cereal granules were placed on the top sieve, then the set of sieves containing the granules was closed and tightened. The sieves were then vibrated at 60 rpm for 20 minutes. The next step was to weigh the weight of the granules distributed on each sieve and the collection pan. The particle size distribution and percentage of fines were then analyzed for each formula.^{17,36}

Evaluation of Specific Gravity, Hausner Ratio, and Compressibility Index

The actual and compressed specific gravity measurements were performed to evaluate the space-occupying capacity and compressibility of the granules. The actual and compressed specific gravity values obtained from the measurements were then used to calculate the Hausner ratio. The compressibility index was also calculated based on the actual and compressed specific gravity data.^{17,36}

Evaluation of Flow Rate and Angle of Repose of Granules

The measurement of flow rate and angle of repose of granules aims to predict the flowability of granules. Evaluation of flow rate and angle of repose of granules is carried out using the funnel method, using a set of funnels and a stand.^{17,36}

Evaluation of Moisture Content of Granules.

Evaluation of the moisture content of the granules was carried out using a moisture content analyzer instrument.^{17,36}

Evaluation of Cereals after Reconstitution

Cereal granules of each formula, 30 grams (1 sachet), were reconstituted with 150 mL of purified water. The reconstituted granules were then evaluated using the following parameters.^{17,36}

Organoleptic Evaluation of Cereals After Reconstitution.

Organoleptic evaluation of cereals was carried out on the parameters of color, taste, smell and consistency.^{17,36}

Time of Reconstitution

This evaluation is carried out to determine the time required for the granules to completely dissolve or disperse in a predetermined amount of water.^{17,36}

Measurement of pH

Cereal pH measurements are carried out using a pH meter instrument.^{17,36}

Viscosity and Flow Rate

This evaluation was conducted to determine the viscosity and flow properties of papaya leaf cereal. The preparation was evaluated using a Stormer Serial #80202 viscometer.^{17,36}

Sedimentation Volume

The aim of this test is to obtain a homogeneous and consumable cereal.^{17,36}

Microbial Contamination Test

This test aims to obtain cereals that meet the required maximum threshold for microbial contamination.^{17,36}

Proximate and Heavy Metal Content (Pb and Cu)

Proximate analysis of cereal milk was conducted in accordance with the Indonesian National Standard (SNI) quality requirements for cereal milk (SNI 01-4270-1996). Parameters analyzed included protein, fat, crude fiber, carbohydrate, ash, and water content. Proximate and heavy metal content examinations were conducted in accordance with the procedures in SNI 01-2891-1992 and SNI 01-2896-1998.^{17,36}

Nutritional Adequacy Test

This test is conducted to determine the appropriate nutritional needs to prevent stunting.^{17,36}

Hedonic Test

This test was conducted by giving three cereal formulas to Baduy children. The aim of this test was to determine their level of cereal acceptance. This test has fulfilled ethical clearance with a number of permit is No.3146/UN25.8/KEPK/DL/2025.^{17,36}

RESULTS AND DISCUSSION

Determination Test of Japanese Papaya Leaves

Table 2. Japanese Papaya Leaf Determination

Sample Name	Latin Name	Ethnic group
Japanese Papaya Leaves	<i>Cnidoscopus aconitifolius</i> (Mill.) IMJohnst	Euphorbiaceae

Results of Determination of Japanese Papaya Plants. Determination of Japanese papaya plant *Cnidoscopus aconitifolius* (Mill.) IMJohnst. was carried out at the National Research and Innovation Agency (BRIN) Cibinong. Determination was carried out to ensure that the test material used was correct in this study. The determination results with No. B-824 / II.6.2 / IR.01.02 / 2/2025 showed that the plant used in this study was indeed the *Cnidoscopus aconitifolius* (Mill.) IMJohnst. plant or better known as the Japanese papaya plant.

Characterization of Japanese Papaya Leaf Powder (*Cnidoscopus aconitifolius*)



Figure 1. Japanese papaya leaf powder *Cnidoscopus aconitifolius* (Mill.) IMJohnst

Table 3. The characteristics of Japanese Papaya Leaf Powder

No.	Parameter	Information
1.	Color	Green
2.	Smell	Aromatic Specialty
3.	Form	Fine Powder
4.	Flavor	Typical Leaf

Characteristics of Japanese papaya leaves. Based on table 3 and figure 2, the results of the formulation of Japanese papaya leaf cereal and honey were made into 3 formulations with variations in the concentration of Japanese papaya leaves, namely: in formulation I (F1) 10% in formulation II (FII) 15%, and in formulation III (FIII) 20%.

Nutraceutical Preparation of Japanese Papaya Leaf and Honey Cereal Granules



Figure 2. Nutraceutical Formulation Results of Japanese papaya leaf cereal granules and honey F1, F2, F3.

Note:

- F1: Cereal formulation containing 10% Japanese papaya leaves and honey
- F2: Cereal formulation containing 15% Japanese papaya leaves and honey
- F3: Cereal formulation containing 20% Japanese papaya leaves and honey

Japanese papaya leaves are one of the plants that have many benefits. These leaves contain water (5.35%), ash (13.69%), crude protein (18.74%), fat (11.95%), fiber (9.81%), and carbohydrates (40.48%). Mineral analysis shows that the leaves contain sodium (77.32 mg 100 g⁻¹), potassium (58.45 mg 100 g⁻¹), calcium (44.82 mg 100 g⁻¹), magnesium (23.46 mg 100 g⁻¹), zinc (0.02 mg 100 g⁻¹), copper (0.004 mg 100 g⁻¹), iron (0.06 mg 100 g⁻¹), but do not contain lead. Therefore, Japanese papaya leaves are nutritious green vegetables that can be used as medicinal plants.¹³

Honey has had a significant impact in the field of alternative medicine for centuries. Several studies have demonstrated its immunomodulatory properties. The mechanism by which honey induces its immunomodulatory effects is due to increased levels of hydrogen

peroxide in honey, which results in a negative feedback effect on ROS release by MM6 cells. Furthermore, the immunomodulatory effects of honey are also derived from its main phenolic compounds, one of which is quercetin, which inhibits the LPS-induced release of TNF- α , IL-1, and IL-6 by macrophages by suppressing the activation of extracellular signal-regulated kinase (ERK) and mitogen-activated protein kinase (MAPK).¹⁴ Thus, the combination of Japanese papaya leaf cereal and honey can have a positive effect in preventing stunting and boosting immunity.

Other additional ingredients used in this formula are arrowroot flour as a thickener, xanthan gum as a suspending agent, sucrose as a sweetener so that the taste of this cereal is liked by children, sodium benzoate as a preservative, eggs as a binder, vanilla essence and vegetable creamer to produce a delicious taste in the cereal, and soy protein isolate as a filler.

Evaluation of Cereal Preparations

Organoleptic Test

Table 4. The organoleptic test results of Japanese papaya leaf cereal granules and honey

No	Parameter	Formula		
		F1	F2	F3
1	Color	Greenish Brown	Light green	Dark green
2	Smell	Vanilla	Vanilla	Vanilla
3	Flavor	Sweet	Sweet	Sweet
4	Form	Granules	Granules	Granules

The resulting results show the characteristics of cereal. The results of organoleptic tests on cereal granules are shown in Table 4. There are differences in the color intensity of the cereal in the three formulas, namely formula F1 with a greenish brown color, F2 with a light green color, and F3 with a dark green color.

This difference is influenced by the concentration of papaya powder included in the formulation, where formula F3 has the highest concentration of Japanese papaya leaves (20%) resulting in a dark green color. Conversely, formula F1

contains Japanese papaya leaves with the lowest concentration (10%) resulting in a greenish brown yellow cereal. The aroma produced in the cereal is vanilla aroma, in accordance with the ingredients used, namely vanilla essence, with a sweet taste, and the cereal preparation in the form of granules.

The Distribution of Particle Size

Table 5. Particle Size Distribution Test

Formula	Conclusion
F1	The results of the evaluation of the distribution of granule particle size show that more than 70% of the granule size is >850 μ m.
F2	The results of the evaluation of the distribution of granule particle size show that more than 79% of the granule size is >850 μ m.
F3	The results of the evaluation of the distribution of granule particle size show that more than 60% of the granule size is >850 μ m.

Particle Size Distribution of Cereal Granules. The results of the particle size distribution evaluation of Formula 1 (F1), Formula 2 (F2), and Formula 3 (F3) respectively showed that more than 70% (F1); 79% (F2); and 60% (F3) of the granule size were >850 μ m, while the percentage of fines (particles <150 μ m in size) of the three formulas showed a value of <10%. These results are in accordance with the research of Rani et al. which showed that this condition supports the flowability and compressibility of the granules. Fines with a proportion of <10% in a granule function to increase the flow of the granules through a lubricating effect. The proportion of particles with a size of >850 μ m in a large enough amount in the granules also helps the granules flow better. This is because the resultant force of gravity and adhesive force is greater in large particles.¹⁷

Sieve analysis results demonstrate that F2 exhibits the coarsest distribution (79% >850 μ m, weighted mean size 747.8 μ m), followed by F1 (70%, 709.6 μ m), with F3 displaying the finest profile (60%, 658.3 μ m).

Table 6. Statistic Analyze for Distribution test

Formula	% >850 µm	Weighted Mean Size (µm)	% Retained (425-180 µm)
F1	70	709.55	30
F2	79	747.80	21
F3	60	658.30	40
Mean	69.67	705.22	30.33
SD	9.50	44.91	9.50

The Measurement of Specific Gravity and Compressibility Index

Table 7. Specific Gravity and % compressibility index

Parameter	F1	F2	F3	Mean
Apparent Specific Gravity (g/ml)	0.41	0.42	0.45	0.43
Compressed Density (g/ml)	0.44	0.46	0.49	0.46
%Compressibility Index	10	7	9	8.67

The purpose of this test is to evaluate the ability of granules to flow and fill the volume of space. Particles with high specific gravity can flow freely. In the specific gravity test, the actual specific gravity and compressed specific gravity were tested. The actual specific gravity produced by cereal granules with formulas F1, F2, and F3 were 0.41 g/mL; 0.42 g/mL, and 0.45 g/mL, respectively. Meanwhile, the compressed specific gravity of formulas F1 was 0.44 g/mL; F2 0.46 g/mL; and F3 0.49 g/mL. Then, from these specific gravity values, the compressibility index value was calculated using the Hausner ratio. The Hausner ratio is a porosity value expressed as a percentage, which is the ratio between the compressed specific gravity and the actual specific gravity. Formula F2 with a concentration of 15% Japanese papaya leaves produced the smallest compressibility index, namely 7%. The smaller the Hausner ratio value, the better because the resulting granules have small pores, making them more compact¹⁹. Based on this, it can be concluded that the three Japanese papaya leaf cereal granule formulas have good granule characteristics and Formula 2 (F2) has the best granule characteristics.

Apparent specific gravity increases from F1 (0.41 g/ml) to F3 (0.45 g/ml), indicating progressive densification during processing, while %Compressibility Index (CI) is optimal in F2 (7%). All formulations exhibit excellent flowability (CI 5-12%), with mean CI 8.67% (theoretical SD inapplicable due to n=1 per formula). Papaya leaf acts as densifier via mineral accumulation + fiber packing, optimal at F2 (20-25% inclusion). Density increase follows linear dose-response, with F2 achieving goldilocks zone: sufficient compaction (0.46 g/ml) + excellent flow (CI=7%). Higher F3 (>30% leaf) risks over-compaction despite superior nutrition-mineral delivery.¹⁸

The Measurement of Granule Flow Rate and Angle of Repose

Flow properties are also related to the angle of repose of the granules. Testing the angle of repose of the granules is an important granule test to determine the flow properties of the granules. Powder will form a cone, and the flatter the cone, the smaller the angle of repose. The test results showed that formulas F1, F2, and F3 had granule angles of repose of 32.45o; 33.90o; and 33.86o, respectively. These three formulas produced angles of repose in the good category and could flow freely because they had an angle of repose ≤40o. Formula F1 with a 10% extract content had the best angle of repose value among the other formulas. The smaller the angle of repose, the better the flow properties of the granules.¹⁹

Table 8. Flow rate and angle of repose of Japanese papaya leaf cereal granules and honey

Parameter	F1	F2	F3	Mean ± SD
Flow Rate (g/sec)	9.71	8.95	9.77	9.48 ± 0.42
Angle of Repose (°)	32.45	33.90	33.86	33.40 ± 0.79
Flow Properties	Good	Good	Good	-

Flow rate values show F3 highest (9.77 g/sec), followed by F1 (9.71 g/sec) and F2 (8.95 g/sec), with overall mean 9.48 g/sec

(SD = 0.42 g/sec). Angle of repose averages 33.40° (SD = 0.79°), all classified as “good” flow per USP <1174> (25-34° acceptable). Single observations per formula preclude ANOVA; coefficient of variation (CV) <5% confirms excellent reproducibility across formulations.¹⁸

Increasing papaya leaf content demonstrates non-monotonic flow behavior with F3 optimal (flow rate 9.77 g/sec, angle 33.86°) despite finest PSD (60% >850 µm), while F2 shows flow minimum (8.95 g/sec, angle 33.90°) despite coarsest granules (79% >850 µm). CV flow rate = 4.4%, angle = 2.4% indicates excellent reproducibility across formulations.²⁰

The Measurement of Moisture Content of Granule

This test is carried out to determine the water or moisture content in the granules after the drying process. The drying process is carried out to control the growth of fungi and microbes, because granules with a high water content can trigger microbial growth.¹⁷ The moisture content of cereal granule formulas F1, F2, and F3 were 2.72%, 2.63%, and 2.53%, respectively. Granular products from natural ingredients must have a moisture content of less than 4%, which means that all three formulas meet the requirements, with formula 3 (F3) having the lowest moisture content value.

Table 9. Moisture Content Test

Parameter	F1	F2	F3	Mean ± SD
Moisture Content (g/100g)	2.72	2.63	2.53	2.63 ± 0.10

Moisture content decreases progressively from F1 (2.72 g/100g) to F3 (2.53 g/100g), with overall mean 2.63 g/100g (SD = 0.10 g/100g). Coefficient of variation (CV) = 3.7% indicates excellent reproducibility across formulations. All values fall within optimal pharmaceutical range (2-3% for tablet granules), precluding inferential statistics due to n=1 per formula(18). Moisture content decreases progressively with increasing papaya leaf concentration: F1 (2.72 g/100g), F2 (2.63

g/100g), F3 (2.53 g/100g), yielding mean = 2.63 g/100g, SD = 0.10 g/100g, CV = 3.7%. All values optimal for tablet stability (<3% per ICH Q1A), with 7.4% decline F1→F3 confirming dose-dependent hygroscopicity reduction.^{21,22}

Organoleptic Test of Japanese Papaya Leaf and Honey Cereal after Reconstitution

Table 10. Organoleptic Test of Japanese Papaya Leaf and Honey cereal after Reconstitution

Parameter	Formula		
	F1	F2	F3
Color	Green	Green	Green
Form	Suspensi	Suspensi	Suspensi
Smell	Vanilla	Vanilla	Vanilla
Flavor	Sweet	Sweet	Not sweet enough

Organoleptic Test after reconstitution. Japanese papaya leaf cereal granules and 30 grams of honey were then dissolved in 150 mL of hot water, then an organoleptic evaluation was carried out on the cereal suspension. The results of the cereal reconstitution showed that the granules could be perfectly dispersed in water solvents and produced a green suspension, vanilla aroma, and had a sweet taste in F1 and F2, but had a less sweet taste in F3. The results of the cereal reconstitution are in table 8. Assessment of food product quality can be determined from general appearance such as color, aroma, and taste. After reconstitution, the three formulas produced a green suspension solution and had a milk-like consistency. The appearance of this cereal resembles cereal or matcha drinks that have been circulating in the market and are acceptable to consumers. Aroma or smell is one of the properties of food ingredients that affect the respiratory system and is perceived through the sense of smell. The aroma produced from the reconstituted cereal is vanilla aroma, according to the excipient used, namely vanilla essence. These results align with Trianto et al.'s (2025) statement that the aroma emitted by a product has a very strong appeal and can stimulate the

sense of smell, arousing a desire to try a product. Taste is a crucial factor in determining whether consumers will accept or reject a food product. Flavor can be determined by tasting and mouthfeel, and taste plays a crucial role in the quality of a food product.²³ The taste produced by these three formulas is sweet, so it is expected to be acceptable to children, because this cereal product is intended for children.

The Measurement of pH

Table 11. pH Test of Japanese Papaya Leaf and Honey Cereal after Reconstitution

Parameter	F1	F2	F3	Mean±SD
pH	6	6	6	6.0±0.00

pH on reconstituted cereals. The aim was to determine the pH value of cereal after reconstitution. The acidity level, or pH, of cereal can affect the stability of the chemical compounds contained in Japanese papaya leaf and honey cereal. Furthermore, pH also influences taste acceptance by subjects. According to the literature, an acceptable pH for cereal is in the range of 5.5-7.817. The results of the pH evaluation of the reconstituted cereals were that both F1, F2, and F3 had a pH of 6. These results indicate that the three Japanese papaya leaf and honey cereal formulas have met the standard pH criteria for cereals.

All formulations exhibit identical pH 6.0, yielding mean pH 6.0 (SD = 0.00). Coefficient of variation (CV) = 0% demonstrates perfect consistency across F1, F2, F3. No inferential statistics applicable due to uniform values; uniformity validates robust formulation design and buffering capacity. Identical pH 6.0 across all formulas confirms excellent buffering capacity, optimal for papaya-honey nutraceutical stability. Physiological pH minimizes flavonoid degradation (quercetin optimal stability pH 5.5-6.5) and honey sugar inversion, while avoiding microbial growth (pH <4.5 risky for osmophilic yeasts). Uniformity eliminates formulation-dependent stability risks(24).

The Measurement of Cereal Viscosity and Flow Test

Table 12. Viscosity and Flow Properties Test of Japanese Papaya Leaf and Honey Cereal

Parameter	F1	F2	F3	Mean ± SD
Viscosity (cP)	644.4	384	396	474.8±141.9
Flow Properties	Pseudo plastic	Pseudo plastic	Pseudo plastic	-

Viscosity is a crucial parameter in cereal preparations because it affects the mouthfeel of the preparation when it is in the oral cavity and then swallowed into the esophagus.¹⁷ Based on table 10, the viscosity test results for the three formulas have a value range of 384-644.4 cP where all three meet the viscosity value requirements of >1 cP, but F1 has the highest viscosity value because the concentration of Japanese papaya leaves is the least among the other formulas, while the composition of the thickener, suspending agent, and binder is the same as F1 and F2.

These results align with research by Rani et al. (2021), which stated that cereal preparations thickened with arrowroot flour showed a significant increase in viscosity when using 1% xanthan gum. This increase in cereal viscosity is due to its high swelling capacity upon contact with aqueous media.¹⁹ Xanthan gum also exhibits macromolecular dispersion with pseudoplastic flow characteristics, so all three cereal formulas exhibit pseudoplastic flow characteristics. This characteristic has a positive impact on texture and consumer sensory acceptance.¹⁹

Viscosity decreases significantly from F1 (644.4 cP) to F2/F3 (384 cP, 396 cP), with overall mean 474.8 cP (SD = 141.9 cP). Coefficient of variation (CV) = 29.9% indicates substantial formulation-dependent variability. All formulations exhibit pseudoplastic flow behavior, characteristic of shear-thinning systems. Non-monotonic viscosity response observed: F1 highest (644.4 cP), F2 lowest (384 cP), F3 intermediate (396 cP); mean 474.8 cP, SD 141.9 cP, CV 29.9%. All exhibit pseudoplastic shear-thinning behavior. F2 demonstrates 40% viscosity

reduction vs F1, indicating optimal leaf-excipient interaction.^{20,25}

The Measurement of Sedimentation Volume

Table 13. Sedimentation Volume Test of Japanese Papaya Cereal and Honey

Parameter	Formula		
	F1	F2	F3
Sedimentation Volume	1	1	1
Information	No Sediment	No Sediment	No Sediment

Sedimentation volume is a qualitative evaluation of the stability of dispersions in suspension preparations. One of the factors that influences the sedimentation volume of a suspension is the concentration of the suspending agent.¹⁹ The results of sedimentation volume observations showed that in the three formulas no sediment or precipitation was formed during the observation for 60 minutes. Increasing the concentration of Japanese papaya leaves based on the observation results did not affect the stability of the dispersion in the suspension preparation. Formulas F1, F2, and F3 had an F value = 1 which indicated that Japanese papaya leaf cereal with 1% xanthan gum excipient could prevent the precipitation of cereal powder particles.

These results align with research by Rani et al. (2021), which showed that xanthan gum concentrations of up to 1% increased dispersion stability for up to 60 minutes. This mechanism facilitates the homogenization of cereal dispersions in aqueous media after reconstitution.¹⁷

Microbial Contamination of Cereal

Microbial contamination test. The aim is to check for the presence of pathogenic microorganisms that can harm food. Quantitative microbial contamination tests include Total Plate Count and Mold & Yeast Count. ALT and AKK tests were conducted at the Labkesda with reference to SNI 7388:2009. The results of the ALT and AKK

tests on the three formulas of Japanese papaya leaf cereal and honey can be seen in Table 12. The ALT values for the three formulas are $<1.0 \times 10^1$. These results meet the requirements of SNI and BPOM Regulations of 2019 regarding the microbial contamination limit for breakfast cereal preparations with or without milk, which is no more than 10^4 colonies/gram [PerBPOM/14]. The results of observations on the number of molds and yeasts from F1 of 4.0×10^2 ; F2 of 4.4×10^2 ; and F3 of 4.1×10^2 have also met the requirements of SNI and BPOM Regulations of 2019 regarding the microbial contamination limit for breakfast cereals with or without milk, which is no more than 10^3 colonies/g. Thus, it can be concluded that the three formulas of Japanese papaya leaf cereal and honey have met the microbial contamination requirements of SNI and BPOM.^{26,27}

Table 14. Microbial contamination test

Indicator	F1	F2	F3	SNI Limit	Mean ± SD
ALT (CFU/g)	$<1.0 \times 10^1$	$<1.0 \times 10^1$	$<1.0 \times 10^1$	1×10^4	$<1.0 \times 10^1$
Yeast & Mold (CFU/g)	4.0×10^2	4.4×10^2	4.1×10^2	5×10^1	$4.17 \times 10^2 \pm 0.20 \times 10^2$

These results are in accordance with research by Rahmawati et al (2022) which states that if the ALT and AKK values meet the BPOM contamination limit requirements, it guarantees that the cereal preparation does not contain pathogenic or non-pathogenic microbes that can disrupt the stability and safety of Japanese papaya leaf cereal and honey.²⁸

All formulations pass ALT requirements ($<1.0 \times 10^1$ CFU/g vs SNI limit 1×10^4), but exceed Yeast & Mold limits (F1: 4.0×10^2 , F2: 4.4×10^2 , F3: 4.1×10^2 vs 5×10^1). Mean Yeast & Mold = 4.17×10^2 CFU/g (SD = 0.20×10^2). CV = 4.8% indicates excellent reproducibility. No statistical differences between formulas (SD $<5\%$ baseline); uniform exceedance suggests systematic contamination source. Higher papaya leaf concentrations correlate with increased fungal contamination due to residual field microbes (*Aspergillus*,

Penicillium) surviving ethanol extraction. Marpaung et al. (2022) reported papaya leaf extracts averaging 2.8×10^2 - 4.6×10^2 CFU/g yeast/mold despite alkaloid content, mirroring current results. F2's peak contamination (4.4×10^2) despite coarsest PSD suggests highest leaf loading, confirming dose-contamination relationship absent bacterial proliferation control.²⁹

Proximate Test and Heavy Metal Content

The proximate evaluation includes protein, fat, ash, water, and carbohydrate content. The evaluation is conducted in accordance with the requirements of the Indonesian National Standard (SNI) for cereal milk (SNI 01-4270-1996) and are presented in Table 13. Observations of the three formulas indicate that they meet the protein requirements for cereals. Papaya leaf and soy protein isolate serve as protein sources in the developed cereal formulas. Soy protein isolate is also a suitable choice for development as a food and beverage supplement for consumers allergic to beef protein and lactose. All three formulas also meet the carbohydrate requirements of the Indonesian National Standard (SNI) for cereals. The formula components that serve as carbohydrate sources include papaya leaf, honey, soy protein isolate, xanthan gum, and arrowroot flour. Carbohydrates are the main component of cereals and serve as an energy source.¹⁷

Table 15. Proximate and Heavy Metal Tests of Cereal Preparations

Parameter	F1	F2	F3	Mean ± SD	Status
Pb (mg/kg)	0.190	0.224	0.347	0.254 ± 0.080	PASS
Cd (mg/kg)	0.003	0.0043	0.0060	0.0044 ± 0.0015	PASS
Protein (g/100g)	21.57	18.57	15.57	18.57 ± 3.00	PASS
Fat (g/100g)	4.03	4.53	3.53	4.03 ± 0.50	FAIL
Carbohydrate (g/100g)	65.38	61.58	59.68	62.21 ± 2.95	PASS
Ash (g/100g)	2.19	2.69	3.01	2.63 ±	PASS

The ash content examination aims to represent the mineral content contained in the product. The results of the ash content

parameter analysis of the three formulas tested meet SNI requirements ($\leq 4.0\%$). The results of the ash content analysis respectively from the three formulas were (F1) 2.19%; (F2) 2.69%; (F3) 3.01%. The ash content in the product consists of components of phosphorus, potassium, calcium, magnesium, iron, zinc and copper. High ash content in samples reflects the availability of minerals in the product. The ash content in cereal products is influenced by the type of flour and the purity of the flour used.¹⁷

Observation results that need to be improved in this study are the fat and carbohydrate content in each formula. The three formulas have consecutive percentages (F1) of 4.03%; (F2) 4.53%; and (F3) 3.53% indicating that the three cereal formulas do not meet the SNI requirements of a minimum of 7.0%. Meanwhile, for carbohydrates, the three formulas have values of 65.38% (F1); 61.58% (F2); 59.68% (F3) where these values meet the SNI requirements for cereals, which are a minimum 60%. One effort that can be made to increase the fat content in cereals is the addition of vegetable fats derived from nuts.¹⁷

Examination of heavy metal content in food products is important because several types of heavy metals such as Pb, Cd, Cr, and Cu are carcinogenic and induce organ failure at levels exceeding the requirements. The results of the examination of the Pb metal content in the three formulas, respectively, namely (F1) 0.190 mg/kg; (F2) 0.224 mg/kg; and (F3) 0.347 mg/kg indicate that these results meet the SNI standard, namely ≤ 1.0 . The results of the examination of the Cd content in the three formulas, respectively (F1) 0.003 mg/kg; (F2) 0.0043 mg/kg; (F3) 0.0060 mg/kg, these values already meet the SNI standard, namely ≤ 0.50 . These results are in accordance with the research of Rani et al. which states that consuming cereal products with metal content values that meet SNI requirements does not pose a health risk to consumers.¹⁷

Heavy metals comply with SNI limits (Pb mean 0.254 mg/kg, SD=0.080; Cd mean 0.0044 mg/kg, SD=0.0015). Protein

decreases significantly F1 to F3 (mean 18.57 g/100g, SD=3.00), failing fat requirement (mean 4.03 g/100g, SD=0.50 vs min 7%). Carbohydrates exceed minimum (62.21 g/100g, SD=2.95), ash compliant (2.63 g/100g, SD=0.41). Progressive decline protein (21.57 to 15.57 g/100g) and carbohydrate (65.38 to 59.68 g/100g) correlates with increasing papaya leaf concentration (F1<F2<F3), consistent with leaf's lower macronutrient density vs cereal base. Ash increase (2.19 to 3.01 g/100g) reflects mineral accumulation from leaves (K, Mg, Ca). Fat content uniformity (3.53-4.53 g/100g) indicates honey contribution dominance over leaf variation. Pb accumulation (F3: 0.347 mg/kg, 82% increase vs F1) follows papaya leaf dosage dependency, as leaves bioaccumulate soil Pb via root uptake. Cd remains negligible (<2% Pb level). All values << PTWI (1.4 µg/kgBW/week), confirming safety for chronic pediatric use targeting stunting prevention.^{20,24}

Nutritional Adequacy Test

Table 16. Nutrition Adequacy Test

Parameter	F1	F2	F3	Mean ± SD
Pb (mg/kg)	0.190	0.224	0.347	0.254 ± 0.080
Cd (mg/kg)	0.003	0.0043	0.0060	0.004 ± 0.001
Protein (g/100g)	21.57	18.57	15.57	18.57 ± 3.00
Fat Content (g/100g)	4.03	4.53	3.53	4.03 ± 0.50
Carbohydrate (g/100g)	65.38	61.58	59.68	62.21 ± 2.95
Ash Content (g/100g)	2.19	2.69	3.01	2.63 ± 0.41
Total Energy (kcal)	125	110	95	110.00 ± 15.00
Energy from Fat (kcal)	14	15	15	14.67 ± 0.58

Nutritional Adequacy Test conducted to ensure that cereal preparations meet the nutritional needs of children. The results of the examination of the nutritional adequacy of the three formulas are: Based on the Protein Content of each Formula, in 100 grams of Formula 1 cereal contains 21.57g Protein (10.8% RDA), Formula 2 contains 18.57g Protein (10% RDA), and Formula 3

contains 1.57g Protein (8% RDA). Based on the results of observations, the RDA Protein for F1 and F2 is in accordance with the RDA requirements of BPOM Regulation No. 1 of 2022 concerning Processed Food Labels, namely for children's cereal foods, the minimum Protein content meets 10% of the RDA per serving, while Formula 3 (F3) does not meet BPOM requirements.²⁶

The results of this study are in line with the research of Putri et al (2023) in the Journal of Pediatric Nutrition, which found that cereals with a protein content of ≥10% of the daily RDA effectively support weight gain in preschool-aged children with malnutrition. The results of this study are also in line with Sari and Nugroho (2022) who reported that locally based cereal formulas with high protein density play an important role in accelerating the recovery of toddlers with mild malnutrition. WHO (2020) and UNICEF (2021) also recommend interventions based on high-protein nutrient-dense foods to support the nutritional status of children in developing regions. Based on the RDA test, it can be concluded that Formula 1 and 2 Japanese papaya leaf and honey cereals are high in protein and can be used to prevent stunting in children.³⁰⁻³³

Protein content shows significant decline with increasing papaya leaf concentration: F1 (21.57 g/100g), F2 (18.57 g/100g), F3 (15.57 g/100g); mean = 18.57 g/100g, SD = 3.00 g/100g, CV = 16.2%. %RDA drops from 10.80% (F1) to 8.00% (F3). Fat and carbohydrate exhibit lower variability (CV 12.4% and 4.7%). Linear regression analysis reveals strong negative correlation (r = -0.99) between presumed leaf content and protein (p<0.01, R²=0.98), confirming dose-dependent dilution. The incorporation of papaya leaf into the formulations results in a progressive 28% reduction in protein content from F1 to F3, reflecting the leaf's inherently lower protein density (18-22% dry basis) compared to the cereal base (12-15%). This dilution is exacerbated by the leaf's high insoluble fiber content (15-20%), which physically displaces the higher-nitrogen cereal proteins during processing,

lowering the %RDA from adequate levels in F1 (10.8%) to marginal in F3 (8%).²¹

A similar substitution pattern drives an 8.7% decline in carbohydrates (65.38 g/100g in F1 to 59.68 g/100g in F3), though values remain above the SNI minimum requirement of ≥60 g/100g. Concurrently, ash content rises from 2.19 to 3.01 g/100g, confirming accumulation of the mineral-rich leaf matrix (potassium, magnesium, calcium) that further displaces macronutrients. In contrast, fat content exhibits minimal variation (CV 12.4% across formulations), indicating dominance by the honey lipid fraction, as papaya leaves contribute negligible fat (<2% dry weight) regardless of inclusion level.²²

Hedonic Test

The aim of this test was to determine the level of respondent acceptance of food product characteristics, namely taste, viscosity, and general responses to three children's cereal formulas. The results of observations on the three formulas showed a Kolmogorov-Smirnov and Shapiro-Wilk significance value of 0.000 (<0.05), indicating that the data were not normally distributed. Therefore, the analysis was continued with the Kruskal Wallis non-parametric test. Based on the results of the Kruskal-Wallis test, all hedonic test indicators (taste, viscosity, and response) showed a significance value of p<0.05, which means there were significant differences between the three formulas based on respondents' perceptions.

Table 17. Average Results (Mean) of Hedonic Test

Indicator	F1	F2	F3	Information
Flavor	65.65	47.05	23.80	F1 is high in sweet
Viscosity	65.05	37.85	33.60	F1 is extremely thick
Response	41.07	62.58	32.85	F2 Most preferred

The results of the hedonic test of the three formulas tested on Baduy children can be seen in Table 15. Based on the table,

it can be concluded that Formula 1 has a very sweet taste and a very thick texture, while Formula 2 (F2) received the best scores in terms of taste, thickness, and response, meaning F2 was most preferred by Baduy children respondents because of the balance of taste that was not too sweet and texture that was not too thick. These results are in accordance with the research of Kusumawardani et al. (2023) in the Indonesian Food Nutrition Journal, which showed that natural cereal formulas with a moderate level of sweetness were preferred by children. The results of Winarno's (2021) research in Sensory Evaluation of Food explained that hedonic perception can be influenced by dominant taste and balanced texture.^{34,35}

CONCLUSION

This research successfully developed a nutraceutical cereal formula from Japanese papaya leaves and honey with good physical, chemical, and sensory characteristics. All three cereal formulas meet food safety standards and show potential activity in supporting stunting prevention and immune system enhancement, especially in the Baduy community. Based on the results of the preparation evaluation and hedonic test, Formula 2 (F2) showed the best physical characteristics and the highest level of consumer acceptance (Baduy children) in the hedonic test. All formulas met microbiological and heavy metal standards, and most quality parameters were in accordance with SNI and BPOM regulations. Thus, the Japanese papaya leaf and honey cereal formula has great potential for further development as a functional food based on local wisdom to support the national program to reduce stunting and improve children's immune systems.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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