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Development of High-Protein Food Products Using Local Ingredients and Their Nutritional and Sensory Characteristics

Ai Nurhayati[1]*, Rita Patriasih[2], Ai Mahmudatusaadah[3]
Universitas Pendidikan Indonesia
Corresponding Author: Ai Nurhayati ainurhayati@upi.edu

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A B S T R A C T

Nutrition education requires locally sourced foods that are nutritious and acceptable. This study developed a baked mung bean–cassava snack bar and evaluated its nutritional characteristics and sensory acceptability. A quantitative experimental design was applied using four formulations (F1–F4), with increasing mung bean flour and decreasing cassava flour proportions. Each formulation was produced in three independent batches. Protein, fat, carbohydrate, moisture, ash, and energy were analyzed using proximate methods. Sensory acceptability was assessed by 60 untrained panelists using a 9-point hedonic scale. Nutritional data were analyzed using one-way ANOVA or Kruskal–Wallis tests, while sensory data used repeated-measures ANOVA or Friedman tests (α=0.05). Protein increased from 10.39 ± 0.09 g/100 g in F1 to 18.25 ± 0.12 g/100 g in F4. F4 achieved the highest overall acceptability (7.15 ± 0.82) and was selected as the best formulation.

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INTRODUCTION

Malnutrition is still a public health challenge that shows that food availability has not always been followed by the consumption of food with adequate nutritional quality. The latest global estimates show that by 2024 around 23.2% or 150.2 million children under five years old will be stunted, which illustrates the still large problem of chronic malnutrition at the global level. In Indonesia, the prevalence of stunting has decreased from 21.5% in 2023 to 19.8% in 2024, but this figure still shows the need to strengthen food-based interventions that can be applied sustainably. Protein is one of the important macronutrients in growth, tissue maintenance, metabolic function, and growth restoration in malnourished groups. Endrinikapoulos et al. (2023) emphasized that protein adequacy has an important role in supporting catch-up growth and that Indonesia has a variety of local food commodities that have the potential to be developed as protein sources. Therefore, optimizing local food into highly nutritious products is a strategic approach to connect the availability of food resources with improving the quality of public consumption.

From the perspective of nutrition education, improving the quality of consumption is not enough to be achieved just by delivering information about nutrients. Contemporary nutrition education emphasizes food literacy, which is the ability to understand, choose, prepare, and use food appropriately in daily life. Ares et al. (2024) explained that these competencies include functional, relational, and critical aspects that allow a person to translate nutritional knowledge into healthier and more sustainable food decisions. In line with this, the systematic review of Pushpa et al. (2024) shows that nutrition education interventions in young Asian populations in general are able to increase knowledge, self-efficacy, and healthy consumption behaviors. In the Indonesian context, Suciyanti et al. (2025) also found that nutrition education based on food recommendations tailored to the local context increases the consumption of animal and vegetable proteins and protein intake in adolescent girls. The findings suggest that nutrition education would be more meaningful if participants not only received abstract information, but were also introduced to real food choices that are nutritionally valuable, locally available, and relevant to their consumption habits.

Indonesia has a diversity of food ingredients that provide great opportunities for the development of high-protein products based on local resources. In addition to various types of nuts, grains, fish, and traditional food products, local cereal commodities also have nutritional compositions that can be utilized through appropriate combinations and formulations. Winarti et al. (2023), for example, show that there are variations in the content of proteins, amino acids, vitamins, minerals, and other nutritional components in Indonesian rice, corn, and sorghum, so that local food diversification has the potential to support efforts to improve nutrition. At the international level, Tura et al. (2023) succeeded in optimizing the combination of local cereals and legumes into foods with higher protein and energy density than comparable products. Similarly, Hoehnel et al. (2022) showed that the combination of several high-protein ingredients from legumes and pseudocereals can produce products with better

protein profiles without losing the characteristics of key food technologies. The evidence shows that the development of food products requires not only the selection of ingredients based on individual protein content, but also formulations that are able to produce a balance between nutritional composition and final product characteristics.

Although increasing protein content is the main goal of formulations, high nutritional quality does not automatically guarantee consumer acceptance. The addition of certain protein sources can change the color, aroma, texture, taste, and sensation after consumption, thus creating a trade-off between nutrient density and acceptability. Hoehnel et al. (2022) show that the use of high-protein ingredients can affect the technological and sensory quality of products, while the right combination of ingredients is able to maintain characteristics that are close to conventional products. King et al. (2024) also affirm that the processing and formulation of legume-based ingredients can increase protein utilization, but consumer acceptance remains highly dependent on the processing process's ability to control less preferred sensory attributes. In the context of nutrition education, this aspect is becoming increasingly important because foods recommended as healthy choices must be not only nutritious, but also attractive and acceptable to the target. Ng et al. (2022) showed that sensory evaluation of recipes in nutrition education programs can identify attributes such as taste and texture that determine consumers' preferences and intentions to prepare or consume the product.

Nevertheless, the latest literature still shows a separation between nutrition education research and food development research. Nutrition education studies are generally oriented towards changes in knowledge, attitudes, food literacy, or consumption behavior (Ares et al., 2024; Pushpa et al., 2024; Suciyanti et al., 2025), while food technology research focuses more on formulation optimization, increased protein content, or sensory characteristics of products separately (Hoehnel et al., 2022; Tura et al., 2023; King et al., 2024). On the other hand, evidence from Ng et al. (2022) shows the importance of incorporating sensory evaluation into the development of food materials for nutrition education. Based on this synthesis, research is still needed to simultaneously develop several formulations of high-protein products from local foods, objectively test their nutritional composition, compare their sensory acceptance, and place the resulting products as a concrete form of translating nutrition education messages. Thus, the research gap does not solely lie in the unavailability of high-protein products, but in the limited integration between nutritional value, sensory acceptance, local food utilization, and educational relevance in one product development framework.

Among various local food resources, mung bean (Vigna radiata) and cassava (Manihot esculenta) represent complementary ingredients for food product development. Mung bean flour can contribute a relatively higher protein fraction, whereas cassava flour provides a carbohydrate-rich matrix suitable for snack development. In this study, both ingredients were incorporated into a baked snack bar, with mung bean flour serving as the principal protein-contributing ingredient. The proportion of mung bean flour was progressively increased across four formulations, while the proportion of cassava flour was correspondingly reduced. This formulation strategy was designed to determine whether increasing the contribution of a local plant protein source could improve the nutritional profile of the product without reducing sensory acceptability.

Based on these gaps, this study aims to develop a mung bean–cassava snack bar using local food ingredients and to analyze differences in nutritional characteristics and sensory acceptability among four formulations (F1–F4). Nutritional characterization includes protein, fat, carbohydrate, moisture, ash, and energy, while sensory acceptability is evaluated based on color, aroma, taste, texture, and overall acceptability. The study further aims to identify the formulation that provides the most favorable balance between protein content and consumer acceptance.

LITERATURE REVIEW

Local Ingredients as Sources of High-Quality Protein

The use of local foods is an important approach in the development of high-protein products because it can increase nutritional value while supporting the diversification and sustainability of the food system. Indonesia has a variety of cereals, legumes, fish, and traditional foods that have the potential as a source of protein. Winarti et al. (2023) show that Indonesia's local cereals, including rice, corn, and sorghum, have a variety of protein, mineral, vitamin, and bioactive components content that allows their use in nutritious food formulations. Meanwhile, Endrinikapoulos et al. (2023) emphasized that various local Indonesian commodities can contribute to meeting protein needs, especially in supporting growth and improving nutritional status. This potential is even stronger when cereals are combined with legumes or other protein sources to produce a more balanced nutrient profile. Thus, the selection and proportion of local ingredients are fundamental factors in the development of high-protein products.

In the present study, mung bean flour was selected as the principal local plant-protein ingredient, while cassava flour was used as the main carbohydrate-based ingredient. The combination was selected to create a practical local-food product in which increasing proportions of a protein-rich legume ingredient could be evaluated against changes in proximate composition and sensory acceptability. Both ingredients were developed into a baked snack bar to provide a ready-to-consume product suitable for nutritional and sensory evaluation.

Formulation and Nutritional Characteristics of High-Protein Foods

The product formulation determines the chemical composition and nutritional quality of the food produced. Hoehnel et al. (2022) showed that the combination of high-protein ingredients from faba beans, lupines, and buckwheat in pasta was able to improve nutritional quality compared to conventional wheat-based formulations. Similar findings were reported by Tura et al. (2023), which showed that the combination of dabi teff, field pea, barley, oats, linseed, and corn produced a product with a higher protein content and protein density than the control product; the optimal formulation reached 15.74%. Makhloufi and Yamani (2024) also found significant differences in protein, fat, fiber, carbohydrates, energy, ash, and moisture content between products made using different types of legumes. The evidence shows that changes in the type and proportion of ingredients are direct determinants of product proximate characteristics, so the analysis of proteins, fats, carbohydrates, moisture content, ash, and energy is an important indicator in determining the best formulation.

Processing, Protein Quality, and Product Characteristics

In addition to the composition of ingredients, the processing process can modify the protein characteristics and final quality of the product. King et al. (2024) explained that various legume processing techniques can improve protein digestibility while affecting the structure and acceptance of products. In the context of Indonesian local food, Astawan et al. (2024) showed that the germination process in velvet beans (Mucuna pruriens) used in making tempeh changes physicochemical characteristics such as texture, pH, antioxidant capacity, and sensory characteristics. The findings confirm that high protein content alone is not enough to be the basis for assessing product quality, because simultaneous formulation and production processes can affect the nutritional value, texture, color, taste, and other attributes of the product. Therefore, the development of high-protein foods requires a multidimensional evaluation between the composition of the ingredients, processing methods, and characteristics of the final product.

Sensory Characteristics and Consumer Acceptability

The success of high-nutritious products is highly dependent on sensory acceptance because increased concentrations of protein ingredients can result in changes in color, aroma, taste, and texture. Hoehnel et al. (2022) found that the combination of several high-protein ingredients can maintain the technological and sensory qualities of pasta that are relatively close to conventional pasta, suggesting that optimization of ingredient combinations can minimize the trade-off between increased nutritional value and sensory quality. Makhloufi and Yamani (2024) also showed significant differences in the sensory attributes of legume-based products, with red lentil formulations gaining the highest acceptance and approaching control products. In Indonesian local food products, Astawan et al. (2024) proved that differences in ingredients and processing treatments result in different sensory profiles. Thus, color, aroma, taste, texture, and overall acceptability are essential indicators to ensure that increased protein

results in products that are not only nutritious, but also suitable for consumption and consumer acceptance.

Integration of Nutritional Quality, Sensory Acceptance, and Nutrition Education

In the context of nutrition education, food products that have high nutritional quality need to be translated into food choices that are realistic and acceptable to educational targets. Ng et al. (2022) show that sensory evaluation of recipes used in nutrition education programs can provide important information about consumer acceptance and intention to prepare the food; in particular, taste and texture are important determinants of overall liking. This means that food-based nutrition education should not only emphasize nutrient content, but also need to consider consumption experiences that support the application of nutritional messages in daily life. However, previous research still evaluates many nutritional values or sensory characteristics separately. Therefore, this study positions local food formulations as experimental factors that are simultaneously tested against nutritional characteristics and sensory acceptance, so that the best formulation can be determined based on the balance between protein density and consumer acceptance. This approach provides an empirical basis for the development of local food products that can be used as a high-protein food alternative while supporting food-based nutrition education.

Research Hypotheses

Based on these theories and empirical findings, this study uses two main hypotheses. H1: Differences in local food formulations have a significant influence on the nutritional characteristics of the product, including protein, fat, carbohydrate, moisture content, ash, and energy. H2: Differences in local food formulations have a significant influence on the sensory characteristics of the product, including color, aroma, taste, texture, and overall acceptance. The best formulation is then determined by considering together the increase in protein content and the level of sensory acceptance.

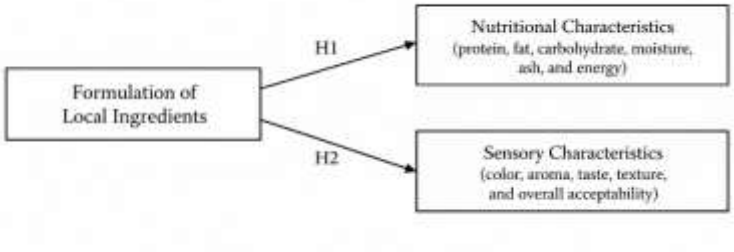


Figure 1. Hypothesis Diagram

METHODOLOGY

Types of Research

This study employed a quantitative experimental approach using a food product development design. A baked mung bean–cassava snack bar was developed using four formulations (F1–F4). The experimental factor was the proportion of mung bean flour relative to cassava flour. Mung bean flour was progressively increased from F1 to F4, whereas cassava flour was reduced proportionally. The proportions of rice flour, palm sugar, palm oil, egg, salt, and baking powder were maintained constant across formulations. Each formulation was produced in three independent batches to evaluate the effect of formulation differences on nutritional characteristics and sensory acceptability.

Materials

The principal local ingredients used in this study were mung bean flour and cassava flour. Mung bean flour was used as the main protein-contributing ingredient, whereas cassava flour functioned as the principal starch-based component. Rice flour was incorporated to support product structure, while palm sugar, palm oil, whole egg, salt, and baking powder were used as supporting ingredients. All ingredients for the four formulations were obtained from the same commercial source or production lot whenever possible to minimize variation in raw-material characteristics. Drinking-quality water was used during dough preparation.

Product Formulation

Four formulations of baked mung bean–cassava snack bars were developed and designated as F1, F2, F3, and F4. The formulations differed in the relative proportion of mung bean flour and cassava flour. Mung bean flour was increased by 10 percentage points between consecutive formulations, whereas cassava flour was decreased by the same proportion. Other ingredients were maintained at constant levels. The basic formulation was standardized to 100 g before the addition of processing water, as presented in Table 1.

Table 1. Composition of the Four Mung Bean–Cassava Snack Bar Formulations

Ingredient (g/100 g formulation)	F1	F2	F3	F4
Mung bean flour	30	40	50	60
Cassava flour	40	30	20	10
Rice flour	10	10	10	10
Palm sugar	6	6	6	6
Palm oil	6	6	6	6
Whole egg	6	6	6	6
Salt	1	1	1	1
Baking powder	1	1	1	1
Total	100	100	100	100

Approximately 20 mL of water per 100 g formulation was added during dough preparation to obtain a workable consistency. Processing water was not included in the 100 g formulation because part of the water evaporated during baking.

Product Preparation

All dry ingredients were weighed according to the formulation and passed through a 60-mesh sieve before mixing. Mung bean flour, cassava flour, rice flour, palm sugar, salt, and baking powder were mixed for approximately 3 minutes until homogeneous. Whole egg and palm oil were then added, followed gradually by approximately 20 mL of water per 100 g formulation. The mixture was kneaded until a uniform dough was obtained and allowed to rest for 10 minutes. The dough was subsequently shaped into rectangular snack bars weighing approximately 20 g per piece. The bars were baked at 160°C for approximately 18 minutes, cooled at room temperature for 30 minutes, and placed in food-grade polyethylene packaging. Samples intended for proximate analysis and sensory testing were obtained from the same production batches and analyzed within 24 hours after preparation. The same processing conditions were applied to F1, F2, F3, and F4.

Population and Sample

The sensory study population consisted of adult consumers who were potential consumers of the developed mung bean–cassava snack bar. A total of 60 untrained panelists were selected by purposive sampling. Inclusion criteria included being 18–45 years old, healthy, having normal taste and smell abilities, willing to participate in the research, and not having an allergy to product ingredients. Panelists provided informed consent prior to testing. The use of untrained panelists was appropriate to assess the level of liking and acceptance of products (Palachum et al., 2023; Qumbisa et al., 2022).

Research Instruments

Research instruments consisted of formulation sheets, laboratory equipment for proximate analysis, and a hedonic test questionnaire. Proximate analysis was conducted on the final baked mung bean–cassava snack bars from F1, F2, F3, and F4, rather than on individual raw ingredients. Protein was determined using the Kjeldahl method, fat using Soxhlet extraction, moisture using the oven-drying method, ash using a muffle furnace, carbohydrate by difference, and energy using Atwater conversion factors. Nutritional data were expressed per 100 g of final baked product (Squeo et al., 2023; Zuñiga-Martínez et al., 2024). Sensory acceptability was assessed using a 9-point hedonic scale, ranging from 1 = dislike extremely to 9 = like extremely, for color, aroma, taste, texture, and overall acceptability (Ruiz-Capillas & Herrero, 2021).

Proximate Analysis

Proximate analysis was performed separately on products obtained from each of the three independent production batches for every formulation. Thus, F1, F2, F3, and F4 each had three independent laboratory observations. Protein, fat, moisture, ash, carbohydrate, and energy were determined for the final baked products. Carbohydrate content was calculated by difference:

Carbohydrate (%) = 100 − [protein + fat + moisture + ash]

Energy content was calculated using Atwater factors:

Energy (kcal/100 g) = (4 × protein) + (4 × carbohydrate) + (9 × fat)

The results therefore represent the proximate composition of the ready-to-consume snack bar, rather than the composition of the raw mung bean or cassava ingredients.

Sensory Evaluation

Sensory evaluation was conducted on the final ready-to-consume F1, F2, F3, and F4 snack bars. All 60 untrained panelists evaluated the four formulations. Each formulation was identified using a randomized three-digit blind code: 314 for F1, 728 for F2, 561 for F3, and 842 for F4. The presentation order was randomized independently for each panelist to minimize order effects. Approximately 10 g of each snack bar formulation was served to each panelist under identical conditions. Panelists evaluated color, aroma, taste, texture, and overall acceptability using a 9-point hedonic scale. Drinking water was provided between samples as a palate cleanser to reduce carry-over effects.

Data Collection Procedure

The study began with the selection and standardization of mung bean flour, cassava flour, and other ingredients, followed by the preparation of four snack bar formulations (F1–F4). Each formulation was produced in three independent batches using the same processing conditions. Final baked products from each batch were subjected to proximate analysis for protein, fat, carbohydrate, moisture, ash, and energy. For sensory evaluation, the four ready-to-consume formulations were randomly coded with three-digit numbers and presented in randomized order to 60 panelists. Drinking water was provided as a palate cleanser between samples. The selected formulation was determined by considering both its measured protein content and sensory acceptability.

Data Analysis Techniques

Data were presented as mean ± standard deviation. Normality was assessed using the Shapiro–Wilk test and homogeneity of variance using Levene's test. Differences in nutritional characteristics among formulations were analyzed using one-way ANOVA followed by Tukey's post hoc test when appropriate; otherwise, the Kruskal–Wallis test was used. Because each panelist evaluated all four formulations, sensory data were analyzed using repeated-measures ANOVA or the Friedman test when parametric assumptions were not satisfied. Statistical significance was set at $p<0.05$.

RESEARCH RESULT

Characteristics of Sensory Test Panelists

A total of 60 untrained panelists participated in a series of sensory tests on four product formulations. The age of the panelists ranged from 18–45 years, with an average age of 30.68 ± 8.22 years. All panelists met the inclusion criteria, namely in good health, had normal taste and smell functions, did not have allergies to product ingredients, and had given *informed consent*. Each panelist assessed the formulations F1, F2, F3, and F4 using a 9-point hedonic scale for color, aroma, taste, texture, and overall acceptance attributes.

Nutritional Characteristics of the Four Mung Bean–Cassava Snack Bar Formulations

Proximate analysis of the final baked mung bean–cassava snack bars showed significant differences in nutritional composition among the four formulations. Protein content progressively increased from 10.39 ± 0.09 g/100 g in F1 to 18.25 ± 0.12 g/100 g in F4. F4 therefore had the highest protein content. Fat, ash, and energy showed progressive increases, while carbohydrate and moisture content decreased as the proportion of mung bean flour increased and cassava flour decreased.

Table 2. Nutritional Characteristics of the Four Final Mung Bean–Cassava Snack Bar Formulations

Parameter	F1	F2	F3	F4	Statistical test	p-value
Protein (g/100 g)	10.39 ± 0.09	12.85 ± 0.14	15.58 ± 0.13	18.25 ± 0.12	ANOVA, F=2341.52	<0.001
Fat (g/100 g)	6.82 ± 0.07	7.12 ± 0.10	7.39 ± 0.01	7.75 ± 0.03	Kruskal–Wallis, H=10.46	0.015
Carbohydrate (g/100 g)	67.72 ± 0.06	65.30 ± 0.10	62.58 ± 0.08	59.96 ± 0.19	ANOVA, F=2385.41	<0.001
Moisture (g/100 g)	13.10 ± 0.05	12.52 ± 0.14	12.04 ± 0.07	11.45 ± 0.12	ANOVA, F=148.94	<0.001
Ash (g/100 g)	1.97 ± 0.03	2.22 ± 0.04	2.42 ± 0.03	2.59 ± 0.03	Kruskal–Wallis, H=10.42	0,015
Energy (kcal/100 g)	373.82 ± 0.45	376.67 ± 0.78	379.15 ± 0.22	382.59 ± 0.35	ANOVA, F=168.55	<0.001

Data are presented as mean ± standard deviation (SD) from three independent production batches.

The results of the analysis showed that there was a significant difference between formulations in all nutritional parameters. The protein content increased by about 75.68% from F1 to F4. Tukey's follow-up test showed a significant difference between formulations in protein, carbohydrates, moisture content, and energy. Meanwhile, fat and ash showed significant differences based on the Kruskal–Wallis test.

Sensory Acceptability of the Four Mung Bean–Cassava Snack Bar Formulations

The results of sensory tests showed an increase in average scores from F1 to F4 on all attributes. F4 obtained the highest average scores for color (7.02 ± 0.81), aroma (7.07 ± 0.94), taste (7.27 ± 0.84), texture (7.20 ± 0.86), and overall acceptability (7.15 ± 0.82).

Table 3. Sensory Acceptability Scores of the Four Mung Bean–Cassava Snack Bar Formulations

Sensory attributes	F1	F2	F3	F4	Friedman χ^2	p-value
Color	6.12 ± 1.01	6.58 ± 0.83	6.87 ± 0.87	7.02 ± 0.81	40.32	<0.001
Aroma	5.90 ± 0.90	6.33 ± 0.73	6.87 ± 0.81	7.07 ± 0.94	68.06	<0.001
Taste	6.10 ± 0.82	6.60 ± 0.96	6.83 ± 0.78	7.27 ± 0.84	60.87	<0.001
Texture	6.07 ± 0.76	6.52 ± 0.75	6.73 ± 0.99	7.20 ± 0.86	57.62	<0.001
Overall acceptance	6.02 ± 0.91	6.42 ± 0.89	6.98 ± 0.72	7.15 ± 0.82	69.92	<0.001

Data are presented as mean ± standard deviation (SD) based on a 9-point hedonic scale.

The Friedman test showed a significant difference in all sensory attributes between formulations ($p<0.001$). Kendall's W values were 0.224 for color, 0.378 for aroma, 0.338 for taste, 0.320 for texture, and 0.388 for overall acceptance, respectively.

Selected Formulation

Based on the combined evaluation of protein content and sensory acceptability, F4 was selected as the best mung bean–cassava snack bar formulation. F4 contained the highest proportion of mung bean flour (60%) and the lowest proportion of cassava flour (10%). The final F4 product contained 18.25 ± 0.12 g protein/100 g and provided 382.59 ± 0.35 kcal/100 g. It also achieved the highest sensory scores for color, aroma, taste, texture, and overall acceptability. Therefore, F4 provided the most favorable combination of increased protein content and consumer acceptance among the formulations tested.

Table 4. Nutritional and Sensory Characteristics of the Selected F4 Mung Bean–Cassava Snack Bar

Indicator	F4
Protein	18.25 ± 0.12 g/100 g
Fat	7.75 ± 0.03 g/100 g
Carbohydrate	59.96 ± 0.19 g/100 g
Moisture	11.45 ± 0.12 g/100 g
Ash	2.59 ± 0.03 g/100 g
Energy	382.59 ± 0.35 kcal/100 g
Color	7.02 ± 0.81
Aroma	7.07 ± 0.94

Taste	7.27 ± 0.84
Texture	7.20 ± 0.86
Overall acceptability	7.15 ± 0.82

Hypothesis Testing Results

The results of the analysis showed that there were significant differences between formulations in all the nutritional characteristics analyzed. Thus, H1 was supported, namely the difference in the formulation of local food ingredients had a significant influence on the nutritional characteristics of the product. In sensory characteristics, all attributes also showed significant differences between formulations with a $p<0.001$ value. Therefore, H2 was supported, i.e. differences in local food formulations had a significant influence on color, aroma, taste, texture, and overall acceptance.

DISCUSSION

The results showed that changes in the proportions of mung bean and cassava flours resulted in marked differences in the nutritional characteristics of the baked snack bars. The protein content increased consistently from 10.39 ± 0.09 g/100 g in F1 to 18.25 ± 0.12 g/100 g in F4, or an increase of about 75.68%, while energy increased from 373.82 to 382.59 kcal/100 g. At the same time, carbohydrates and moisture content decreased, while fat and ash increased. The pattern favors H1 and suggests that ingredient composition is a major determinant of the product's proximate profile. These findings are in line with Tura et al. (2023), who show that the combination of cereals, legumes, and local grains is capable of producing foods with higher protein and energy densities; Their optimum formulation reaches 15.74% protein and energy of 380.43 kcal/100 g. Similarly, Hoehnel et al. (2022) showed that partial substitution of cereals with a combination of high-protein ingredients from legumes and pseudosealia improves the macronutrient profile of the product.

The progressive increase in protein content can be explained by the substitution pattern used in the product formulation. Mung bean flour increased from 30% in F1 to 40% in F2, 50% in F3, and 60% in F4, whereas cassava flour decreased correspondingly from 40% in F1 to 30% in F2, 20% in F3, and 10% in F4. Because mung bean flour contributes a greater protein fraction than cassava flour, increasing its proportion increased the protein concentration of the final product. At the same time, replacing part of the starch-rich cassava flour contributed to the progressive decrease in carbohydrate content from 67.72 ± 0.06 g/100 g in F1 to 59.96 ± 0.19 g/100 g in F4.

The formulation pattern may also explain the moderate increases in fat and ash contents. Although palm oil and the other supporting ingredients were maintained at constant levels across formulations, the progressive increase in mung bean flour altered the overall composition of the product matrix. Consequently, F4 showed not only the highest protein content but also slightly higher fat and ash values than the other formulations. The increase in ash from 1.97 ± 0.03 g/100 g in F1 to 2.59 ± 0.03 g/100 g in F4 may indicate an increase in the total mineral fraction of the product. However, because individual minerals

were not analyzed, this finding cannot be directly interpreted as an increase in specific minerals such as iron or calcium. This interpretation is consistent with Winarti et al. (2023), who reported substantial variation in protein, mineral, vitamin, and other nutritional components among Indonesian local food commodities.

Another important finding is that increased protein was not followed by a decrease in sensory acceptance. In contrast, F4 obtained the highest scores across all attributes, namely color 7.02 ± 0.81, aroma 7.07 ± 0.94, taste 7.27 ± 0.84, texture 7.20 ± 0.86, and overall acceptance 7.15 ± 0.82. All attributes differed significantly between formulations ($p<0.001$), so H2 was also supported. From a product-development perspective, the sensory findings are particularly relevant because increasing mung bean flour did not produce a progressive decline in liking. Instead, F4, which contained the highest proportion of mung bean flour (60%) and the lowest proportion of cassava flour (10%), received the highest scores across all sensory attributes. Within the formulation range examined, this combination therefore appears to provide a favorable balance between the characteristic flavor and texture of the legume ingredient and the structural contribution of cassava and rice flours. The constant levels of palm sugar, palm oil, and egg may also have contributed to maintaining palatability across formulations. This result is important because one of the challenges of developing high-protein foods is the trade-off between increased nutritional value and decreased organoleptic quality. Hoehnel et al. (2022) showed that the precise incorporation of several high-protein ingredients can produce products with better protein content without losing key textural and sensory qualities. King et al. (2024) also concluded that proper processing and formulation can improve the acceptance of legume-based products even if protein concentrations are increased.

However, this pattern of research was not always found in previous studies. Bäuerle and Kühn (2022), for example, found that increased concentrations of pea protein isolate in smoothies can increase less desirable attributes such as a floury, rough, and blunt sensation, which in turn decreases acceptance in some consumers. Karolkowski et al. (2022) also showed that faba bean protein ingredients can produce bitter tastes and green, metallic, and rancid aromas that reduce consumer liking, although heat treatment can reduce some of these characteristics. Unlike the two studies, the sensory scores of F1–F4 in this study actually increased as the protein increased. These differences can logically be influenced by the type and combination of protein sources, the proportion of ingredients, the food matrix, and the conditions of the processing process.

The selection of F4 as the best formulation because it combines the highest protein (18.25 ± 0.12 g/100 g) and the highest overall acceptance (7.15 ± 0.82) suggests that product optimization does not have to choose between nutritional quality and acceptability. These results are in line with the research of Tura et al. (2023), which used a multi-response optimization approach to obtain local food-based products with a balance between protein, energy, and sensory acceptance. This means that the contribution of this study not only identifies formulations with higher protein content, but also demonstrates the importance of using two criteria simultaneously—nutritional quality and consumer acceptance—in establishing optimal formulations. This reinforces a food development approach that is oriented not only on chemical composition, but also on the likelihood of the product actually being consumed by the target. Nevertheless, the higher protein content observed in F4 should be interpreted as a comparative finding within the experimental formulations rather than as a regulatory high-protein nutrition claim.

From the perspective of nutrition education, such sensory acceptance has practical consequences. Local products high in protein will have difficulty functioning as a medium of nutrition education if organoleptically they are not preferred. The F4 findings show the potential to make real products a means of linking knowledge about protein with the experience of choosing and consuming local foods. This approach is relevant to the concept of food literacy, because food education becomes more concrete when participants can recognize, taste, and evaluate food choices. Evidence from Dahmani et al. (2024) shows that sensory experience-based food education can increase knowledge about food groups as well as children's willingness to try legume-based foods, although increasing knowledge does not necessarily directly increase the level of preference. Therefore, the contribution of this research to nutrition education mainly lies in the provision of product candidates that nutritionally and sensorially have the potential to be used in food demonstrations, food literacy learning, or local food-based interventions; The educational effectiveness itself still needs to be tested directly.

Several limitations need to be noted. First, the sensory test only involved 60 untrained panelists aged 18–45 years, so the results could not be generalized to children, adolescents, the elderly, or groups with special protein needs. Second, the study only evaluated momentary intake using a hedonic scale and did not assess purchase intention, willingness to consume repeatedly, and stability of reception during storage. Third, nutrient characterization is limited to proximate analysis so that it does not explain the amino acid profile, protein quality/digestibility, fiber, individual minerals, antinutrients, and bioavailability. The latest literature emphasizes that an increase in the amount of protein is not always synonymous with an increase in the biological quality of protein because the processing process, digestibility, and antinutritional factors also play a role (King et al., 2024). Advanced research should include analysis of essential amino acids and protein digestibility, physical characteristics such as instrumental color and texture, shelf-life, evaluation of production costs, and

sensory testing of nutrition education target populations with larger sample sizes.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that differences in the proportion of mung bean and cassava flours significantly influenced the nutritional characteristics and sensory acceptability of the developed baked snack bars, thereby supporting H1 and H2. Progressive substitution of cassava flour with mung bean flour increased protein content from 10.39 ± 0.09 g/100 g in F1 to 18.25 ± 0.12 g/100 g in F4. Among the four formulations, F4, containing 60% mung bean flour and 10% cassava flour, was selected as the best formulation because it had both the highest protein content and the highest overall acceptability score (7.15 ± 0.82). These findings indicate that mung bean flour has potential as a local plant-protein ingredient for the development of acceptable protein-enriched snack products. The product also has potential to serve as a concrete food-based medium in nutrition education. Further studies should evaluate amino acid profiles, protein digestibility, antinutritional factors, shelf-life, production costs, and effectiveness in nutrition education interventions.

ADVANCED RESEARCH

Further research can be directed at optimizing multiresponse formulations that combine protein quality, sensory acceptance, storage stability, production cost, and educational value. Intervention tests are also needed to assess whether the use of F4 products in nutrition education programs is able to improve food literacy, protein knowledge, healthy food choices, and consumption behavior in the target group.

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