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Quality Characteristics of Tahitian Chestnut (*Inocarpus fagifer*) and Cowpea (*Vigna unguiculata*) Flour Combinations as Ingredients in Snack Bar

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Abstract

The growing demand for convenient, nutritionally balanced snack products has created opportunities for utilizing underutilized local ingredients in food product development. This study aimed to develop snack bar using Tahitian chestnut (*Inocarpus fagifer*) and cowpea (*Vigna unguiculata*) flours as locally available raw materials and to evaluate their physicochemical, sensory, antioxidant, and microbiological characteristics. Five formulations with varying Tahitian chestnut to cowpea flour ratio [A= 1:1; B= 1:5; C= 2:1; D= 1:2; E= 5:1] were prepared using a completely randomized design. The results showed that the incorporation of Tahitian chestnut and cowpea significantly affected ($p< 0.05$) several physicochemical parameters, including color, texture, moisture, dietary fiber, macronutrient composition, and antioxidant properties, while ash content was not significantly influenced. Sensory attributes and microbiological quality were not significantly affected, with all formulations meeting acceptable hedonic and safety criteria. Based on the Zeleny multi-criteria decision method, formulation E (Tahitian chestnut:cowpea ratio of 5:1) was identified as the most balanced formulation among those evaluated. These findings demonstrate the potential of Tahitian chestnut and cowpea flours for snack bar development and provide baseline information for further utilization of local ingredients in value-added food products.

Keywords: Cowpea, Quality, Snack bar, Tahitian chestnut

Introduction

Indonesia faces significant challenges in addressing nutritional needs while promoting the utilization of local food resources. The shift toward modern lifestyles has increased demand for convenient, ready-to-eat foods that can provide sustained energy and essential nutrients (Ghatge, 2023). This trend has created opportunities for developing snack products that combine convenience with nutritional adequacy, particularly using underutilized local ingredients.

Snack bar have emerged as a popular food category due to their portability, extended shelf life, and ability to deliver concentrated nutrition in a single serving. Globally, snack bar consumption continues to grow, with approximately 37% of the world's population consuming these products in 2024, while the Indonesian market is projected to reach USD 32.94 million (Innova Marketing Sights, 2024; Mordor Intelligence, 2024). This growth reflects consumer demand for convenient

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nutrition solutions that fit active lifestyles and varied dietary needs.

Traditional snack bar formulations often rely on imported ingredients or conventional cereals and nuts, creating opportunities for innovation using Indonesia's diverse agricultural resources (Maharani, Pamela, & Kusumasari, 2021). Two particularly promising local ingredients are Tahitian chestnut (*Inocarpus fagifer*) and cowpea (*Vigna unguiculata*), both of which remain underutilized despite their nutritional potential and cultural significance in Indonesian agriculture.

Tahitian chestnut, locally known as *gayam*, was selected in this study due to its potential as an indigenous carbohydrate source with favorable nutritional and functional characteristics. The plant is not cultivated under large-scale plantation systems but grows semi-wild and is traditionally harvested in several regions of Indonesia, including Java and the Maluku Islands (Tetelay & Siahaya, 2018; Veda *et al.*, 2022). Owing to this growth pattern, comprehensive data on cultivated area remain limited. Nevertheless, its consistent availability at the community level and long-standing traditional use indicate its potential as a locally accessible raw material rather than a commodity crop. Previous studies have reported the application of Tahitian chestnut in various food products, such as cookies and crackers (Akhdifa, 2024; Wijanarka *et al.*, 2024). Notably, Tahitian chestnut contains a high dietary fiber content (13.79%) and exhibits a low glycemic index (GI 43), making it suitable for products intended to provide sustained energy (Müller, 2024; Wijanarka, Tifauzah, Khasanah, Nirmala Dewi, & Setyaningsih, 2024). In addition, its flour contributes favorable starch characteristics and textural properties in baked products.

Cowpea (*Vigna unguiculata*) was selected as a complementary ingredient because it is widely cultivated and consumed across Indonesia, including Java, Bali, West Nusa Tenggara, East Nusa Tenggara, Sulawesi, Sumatra, and Kalimantan, with an annual production of approximately 826,351 tons (Fadillah, Purnamawati, & Supijatno, 2020; Tukidi & Erwandi, 2023). Cowpea contributes high-quality plant protein (22.9%) with a relatively low fat content (1.4%) and a rich mineral profile (Anam *et al.*, 2024; Okechukwu-Ezike, Munonye, & Esiegwu, 2020; Olopade *et al.*, 2020). The presence of essential amino acids enhances its value for protein fortification in carbohydrate-based food products. Furthermore, cowpea contributes additional dietary fiber and natural antioxidants derived from its phenolic compounds.

The complementary nutritional characteristics of Tahitian chestnut and cowpea suggest their potential for developing balanced snack bar, in which Tahitian chestnut provides energy-dense carbohydrates and dietary fiber, while cowpea contributes protein and micronutrients. Despite this potential, studies on snack bar formulations based on this specific combination remain limited, particularly regarding the effects of different flour ratios on physicochemical properties, nutritional composition, and sensory acceptance.

Therefore, this study aimed to evaluate the effects of varying proportions of Tahitian chestnut and cowpea flours on the physicochemical characteristics, nutritional composition, sensory attributes, and overall quality of snack bar products, and to identify an optimal formulation that balances nutritional adequacy and product acceptability.

Materials and Methods

Experimental Design

This study used a completely randomized design with one variable, namely the ratio of Tahitian chestnut flour and cowpea flour (1:1; 1:5; 2:1; 1:2; 5:1) in the production of snack bar as presented in Table 1. This study was conducted in triplicate.

Biomaterials and Chemicals

Tahitian chestnut was brought from Yogyakarta, Indonesia, while cowpea was brought from Pasuruan, Indonesia. Other ingredients such as egg whites, skim milk, honey, stevia sugar, salt, and butter were purchased from Blitar, Indonesia. High-purity analytical grade reagents included distilled water, Kjeldahl tablets, hydrogen sulfide, sodium hydroxide, boric acid, BGC-MR, hydrogen chloride, petroleum benzene, ethanol, DPPH, and colony count agar were procured from commercial suppliers.

Preparation of Sample

Process of Production Tahitian Chestnut Flour

The process of making Tahitian chestnut flour was carried out by modifying the method developed by (Rahayu, Safitri, Sulaeman, & Setiawan, 2024). Tahitian chestnut was sorted to select the quality of Tahitian chestnut, such as those that are not rotten. The Tahitian chestnut washed thoroughly, boiled for 45 minutes at 100 ^{o}C, peeled, sliced thinly, and sun-dried for 7 days. The dried Tahitian chestnut ground into flour and sifted with a 60-mesh sieve.

Process of Production Cowpea Flour

The process of making cowpea flour was carried out by modifying the method developed by (Iswahyudi, Khoirunissa, & Putri, 2022; Prestia, Oktavia, Razak, & Pudjirahaju, 2022). Soaking the beans in clean water for 12 hours with a water to bean ratio of 2:1, changing the water every 6 hours. After soaking, the beans boiled for 5 minutes at 100^{o}C, then drained. Once the beans have cooled, the skins peeling off and dried in the sun for 7 days. The dried cowpea was then ground into flour and sifted using a 60-mesh sieve.

Table 1- Formulation of snack bar

Ingredients	A	B	C	D	E
Tahitian Chestnut Flour (g)	37.5	12.5	50	25	62.5
Cowpea Flour (g)	37.5	62.5	25	50	12.5
Egg White (g)	37.5	37.5	37.5	37.5	37.5
Skim milk	12.5	12.5	12.5	12.5	12.5
Honey (g)	15	15	15	15	25
Water (g)	12.5	12.5	12.5	12.5	12.5
Stevia sugar (g)	3	3	3	3	3
Salt (g)	3	3	3	3	3
Butter (g)	25	25	25	25	25

A: The ratio of Tahitian chestnut flour and cowpea flour (1:1)
B: The ratio of Tahitian chestnut flour and cowpea flour (1:5)
C: The ratio of Tahitian chestnut flour and cowpea flour (2:1)
D: The ratio of Tahitian chestnut flour and cowpea flour (1:2)
E: The ratio of Tahitian chestnut flour and cowpea flour (5:1)

Process of Making Snack Bar

The process of making snack bar was carried out by modifying the method developed by (Day, Cakebread, & Loveday, 2022). First, weigh the ingredients according to the formulation in Table 1. Next, mix the ingredients, shape them, and bake them at 130°C for 20 minutes. The baked products are then cooled and packaged.

Quality assessment

Determination of Physical Properties

The physical parameters evaluated for the snack bar were color and texture. Color measurements were performed using a Konica Minolta CR-410 colorimeter (Minolta Camera Co., Osaka, Japan), calibrated with a standard white plate prior to analysis (Anggraeni, Nurwantoro, Budi, & Abduh, 2017). Measurements were recorded in the CIE L*, a*, and b* color space, representing lightness, redness–greenness, and yellowness–blueness, respectively. Each sample was measured at three different surface points, and the mean value was reported. Texture profile analysis was conducted using a Lloyd Texture Analyzer type TAI (Ametek Lloyd Instruments, UK). Samples were compressed using a cylindrical probe (diameter 35 mm) at a crosshead speed of 1 mm/s with a compression distance of 50% of sample height (Puspaningtyas *et al.*, 2024). Hardness, cohesiveness, and adhesiveness were obtained from the force–time curve.

Determination of Chemical Properties

The chemical composition of the snack bar was evaluated by determining moisture, ash, protein, lipid, carbohydrate, and total dietary fiber contents. Moisture content was determined using the gravimetric method (AOAC 925.10), ash content by dry incineration (AOAC 945.46), protein content by the Kjeldahl method based on total nitrogen determination (AOAC 991.22), total dietary fiber by enzymatic–gravimetric analysis (AOAC 985.29), and lipid content by Soxhlet extraction (AOAC 945.39). Carbohydrate content was calculated by difference from the proximate analysis.

Determination of Sensory Properties

Sensory analysis was conducted by modifying the method developed by (Prayitno, Mardiana, & Rochma, 2021). A total of 31 semi-trained panelists evaluated the snack bar samples on five-point hedonic scale. A rating of 1 reflects a strong dislike, while a rating of 5 reflects a strong liking. Ethical clearance for sensory testing has been granted by the ethics commission of State University of Malang with an approval No.19.06.16/UN32.14.2.8/LT/2026.

Determination of Antioxidant Activity

Antioxidant activity was determined using a modified DPPH radical scavenging method according to (Savira, Wahyuni, & Faradilla, 2020). One gram of each sample was extracted with 25 mL of analytical-grade ethanol by maceration for 6 h. The extract was filtered and diluted to concentrations of 50, 100, 200, 300, 400, and 500 mg/L. A blank solution was prepared by mixing 1 mL of DPPH solution with 4 mL of ethanol, and incubation in the dark for 30 min. Absorbance was measured using a UV–Vis spectrophotometer at 513 nm. Antioxidant activity was expressed as IC_{50}, defined as the concentration of sample required to inhibit 50% of DPPH radicals. Lower IC_{50} values indicate stronger antioxidant activity.

Determination of Microbial Properties

The total count of microorganisms in the product was carried out using the method described by (Mardiana, Kurniawan, Wirawantoro, Purnomo, & Prasetiyo, 2023). Five grams of the snack bar sample were weighed, homogenized, and suspended in 45 mL of sterile distilled water to obtain an initial dilution. Subsequently, 1 mL of the suspension was transferred into 9 mL of sterile distilled water to achieve a 10^{-2} dilution. Serial dilutions were then prepared up to 10^{-4}. One milliliter of the appropriate dilution was pour-plated onto Plate Count Agar (PCA) and incubated at 37 °C for 48 hours. Microbial counts were expressed as colony-forming units per gram (CFU/g).

Determination of the Best Treatment

The best treatment was determined using the Zeleny method (Zeleny, 1998) by considering multiple quality attributes, including physical, chemical, microbiological, sensory, and antioxidant characteristics the procedure involved defining an ideal value for each parameter by specifying the desired maximum or minimum performance, depending on the nature of the attribute. All parameters were normalized to a scale of 0–1 to allow direct comparison among variables with different units. Subsequently, the degree of closeness (dk) and the distance to the ideal solution were calculated using L_1 (Manhattan), L_2 (Euclidean), and $L\infty$ (Chebyshev) distance measures. Equal weighting was applied to all parameters to avoid subjective bias and to ensure that each quality attribute contributed equally to the decision-making process. The best treatment was selected based on the minimum distance values (L_1, L_2, and $L\infty$), indicating the formulation closest to the ideal solution.

Statistical Analysis

All experiments were conducted in triplicate. Data were expressed as mean ± standard deviation. One-way analysis of variance (ANOVA) was performed using Minitab 18 (Minitab LLC, Pennsylvania) to analyze variations among samples. Tukey's multiple-range test was used for pairwise comparisons, with statistical significance set at $p<0.05$.

Results and Discussion

Physical Quality of Snack Bar

The physical quality of snack bar is strongly influenced by formulation composition, as ingredient proportions can affect color development and textural characteristics that shape consumer perception. In this study, variations in the ratio of Tahitian chestnut and cowpea flours resulted in significant differences ($p < 0.05$) in color attributes and hardness, while cohesiveness and adhesiveness were not significantly affected (Table 2).

Table 2- Physical quality of snack bar

Parameters	A	B	C	D	E
L*	49.20 ± 0.53[b]	51.97 ± 0.55[a]	47.00 ± 0.44[c]	48.30 ± 0.15[b]	45.43 ± 0.15[d]
a*	3.00 ± 0.10[a]	1.87 ± 0.06[c]	2.50 ± 0.10[b]	2.00 ± 0.10[c]	2.80 ± 0.10[a]
b*	19.63 ± 0.21[a]	18.50 ± 0.10[b]	16.57 ± 0.25[d]	17.23 ± 0.15[c]	16.17 ± 0.15[d]
Hardness (N)	84.44 ± 2.47[a]	86.13 ± 1.00[a]	75.80 ± 1.66[b]	76.20± 1.04[b]	60.46 ± 2.54[c]
Cohesiveness	0.11 ± 0.01[a]	0.26 ± 0.17[a]	0.17 ± 0.05[a]	0.37 ± 0.13[a]	0.54 ± 0.26[a]
Adhesiveness (J)	-0.0035± 0.00[a]	-0.0039 ± 0.00[a]	-0.0023± 0.01[a]	-0.0038± 0.0012[a]	-0.0014 ± 0.00[a]

Expressed values were mean±SD (n = 3); a same row containing means with the same superscript letters are not significantly different ($p < 0.05$).
A: The ratio of Tahitian chestnut flour and cowpea flour (1:1)
B: The ratio of Tahitian chestnut flour and cowpea flour (1:5)
C: The ratio of Tahitian chestnut flour and cowpea flour (2:1)
D: The ratio of Tahitian chestnut flour and cowpea flour (1:2)
E: The ratio of Tahitian chestnut flour and cowpea flour (5:1)

Increasing the proportion of Tahitian chestnut flour was associated with lower lightness (L*) and yellowness (b*) values, accompanied by higher redness (a*) values, resulting in a darker and slightly more reddish appearance. This trend may be attributed to the darker native color of Tahitian chestnut flour and its susceptibility to enzymatic browning during processing, as previously reported by (Wijanarka, Sudargo, Harmayani, & Marsono, 2017). The increase in a* values is consistent with observations by (Ly, Dyer, Feig, Chien, & Del Bino, 2020), who reported that positive a* values indicate a shift toward red hues in cereal-based products.

Textural analysis showed that snack bar hardness decreased as the proportion of Tahitian chestnut flour increased, indicating a more brittle structure. This behavior is likely related to starch composition, particularly the amylose–amylopectin ratio. Tahitian chestnut starch contains moderate amylose levels (24.09%), which may contribute to reduced structural rigidity compared to starches with higher amylose content (Jariyah, Mulyani, & Setya, 2013). Previous studies have shown that higher amylose levels tend to increase hardness, whereas higher amylopectin proportions result in softer textures (Wulandari, Imam, & Syarifah, 2016). In contrast, cohesiveness and adhesiveness were not significantly influenced by formulation differences. These properties are generally associated with overall starch content rather than starch type alone, as reported by (Iswara, Julianti, & Nurminah, 2019). The low adhesiveness values observed across all formulations indicate that the snack bar was not sticky, which is desirable for consumer handling and oral processing (Lee, Chung, Lim, Kim, & Ha, 2025).

Chemical Composition of Snack Bar

The protein, fat, water, ash, carbohydrates, and crude fiber of the snack bar were determined, as presented in Table 3.

Table 3- Chemical composition of snack bar

Parameters	A	B	C	D	E
Protein (%wb)	7.35 ± 0.11^{d}	10.62 ± 0.12^{a}	8.10 ± 0.08^{c}	9.77 ± 0.17^{b}	6.93 ± 0.07^{d}
Fat (%wb)	20.18 ± 0.21^{ab}	18.28 ± 0.29^{c}	20.54 ± 0.25^{a}	20.54 ± 0.24^{a}	19.88 ± 0.20^{b}
Moisture content (%wb)	26.75 ± 0.99^{a}	25.25 ± 0.36^{b}	25.43 ± 0.29^{b}	25.22 ± 0.28^{b}	25.26 ± 0.34^{b}
Ash (%wb)	2.24 ± 0.04^{a}	1.94 ± 0.14^{b}	2.07 ± 0.02^{ab}	2.14 ± 0.03^{a}	2.10 ± 0.02^{ab}
Carbohydrate (%wb)	43.14 ± 0.54^{bc}	44.23 ± 0.44^{b}	44.38 ± 0.44^{b}	42.73 ± 0.45^{c}	46.20 ± 0.49^{a}
Dietary fiber (%wb)	7.76 ± 0.08^{c}	7.10 ± 0.08^{d}	8.37 ± 0.14^{b}	7.58 ± 0.10^{cd}	9.75 ± 0.36^{a}

Expressed values were mean±SD (n = 3); a same row containing means with the same superscript letters are not significantly different ($p < 0.05$).
A: The ratio of Tahitian chestnut flour and cowpea flour (1:1)
B: The ratio of Tahitian chestnut flour and cowpea flour (1:5)
C: The ratio of Tahitian chestnut flour and cowpea flour (2:1)
D: The ratio of Tahitian chestnut flour and cowpea flour (1:2)
E: The ratio of Tahitian chestnut flour and cowpea flour (5:1)

The proportion of cowpea flour influenced the protein content of the snack bar, higher levels of cowpea associated with increased protein content. This indicates that cowpea primarily contributes to protein enhancement in the formulation, while Tahitian chestnut functions mainly as a carbohydrate source. The observed effect was statistically significant ($p < 0.05$), confirming that formulation composition affected protein levels. This trend is consistent with previous studies reporting that greater incorporation of cowpea results in higher protein content in processed food products (Wibowo, Swasti, & Pranata, 2023), which can be attributed to the relatively high intrinsic protein content of cowpea, reported to range from 22% to 24% (Shevkani, 2025). When compared with snack bar formulated using other local ingredients, such as Indian almond seeds (9.28%) (Febrianza, Widawati, & Nur'aini, 2024), the protein content obtained in this study (6.93–10.62%) was within a comparable range. These variations are primarily related to differences in the intrinsic protein composition of the raw materials rather than processing conditions.

Differences in fat content among the snack bar formulations can be explained by variations in the proportion of Tahitian chestnut and cowpea flours, although the relationship appears complex and not strictly linear. Formulation B, which contained the highest proportion of cowpea flour (62.5 g) and the lowest proportion of Tahitian chestnut flour (12.5 g), exhibited the lowest fat content (18.28%), consistent with the low intrinsic fat content of cowpea (0.58–2.03%) (Karuwal, Suharsono, Tjahjoleksono, & Hanif, 2021). In contrast, formulations with moderate to high proportions of Tahitian chestnut flour (C: 50 g; D: 25 g) showed the highest fat content (20.54%), whereas formulation E, with the highest Tahitian chestnut proportion (62.5 g), had an intermediate fat level (19.88%) that was statistically lower than C and D. This non-linear pattern suggests that, although Tahitian chestnut contains higher intrinsic fat (2.95–5.38%) compared to cowpea (Rahayu *et al.*, 2024), increases in its proportion do not necessarily correlate positively with final product fat content. Such behavior may be explained by complex interactions within the food matrix, where mixing efficiency, fat distribution, and thermal processing conditions affect fat retention (Aguilera, 2019). While the fixed addition of butter (25 g, 80% fat) remains the primary contributor to overall lipid content (Pădureţ, 2021).

The moisture content of the snack bar varied among formulations and was significantly affected by the proportion of Tahitian chestnut flour and cowpea ($p < 0.05$). An increase in Tahitian chestnut flour generally resulted in higher moisture levels. This trend can be explained by the starch characteristics of Tahitian chestnut, which exhibits a high capacity for water absorption and retention. Starch molecules contain numerous hydroxyl (–OH) groups that readily form hydrogen bonds with water, thereby enhancing water binding within the product matrix (Donmez, Pinho, Patel, Desam, & Campanella, 2021). As a consequence, snack bar with higher moisture content tended to exhibit a softer texture. Tahitian chestnut starch contains a medium amylose content (approximately 24%), which falls within the typical range of 20–25% (Bhardwaj, Salgotra, & Sharma, 2019; Jariyah *et al*., 2013). This amylose level contributes to improved water retention and influences the compactness and softness of the final product.

Ash content did not differ significantly among snack bar formulations ($p > 0.05$), indicating that variations in the ratio of Tahitian chestnut flour and cowpea had little influence on the overall mineral content of the final products. This result is consistent with previous studies reporting comparable ash levels in Tahitian chestnut flour and cowpea, which may explain the similar mineral contribution across formulations (Karuwal *et al*., 2021; Rahayu *et al*., 2024). The use of fixed amounts of other ingredients, such as egg white, skim milk, and butter, may also have contributed to the limited variation in ash content. The ash values obtained in this study are comparable to those reported for snack bar formulated with other local ingredients, including purple sweet potato (Aurelia, Ma'rifah, & Muhlishoh, 2023).

The carbohydrate content of the snack bar differed significantly among formulations ($p < 0.05$) and showed an increasing trend with higher proportions of Tahitian chestnut flour. Formulations dominated by Tahitian chestnut flour exhibited higher carbohydrate levels compared to those with greater amounts of cowpea flour. This pattern reflects the inherent characteristics of the raw materials, as Tahitian chestnut serves as a primary source of complex carbohydrates, whereas cowpea contributes mainly protein (Müller, 2024). Consequently, formulations dominated by Tahitian chestnut flour exhibited higher carbohydrate levels, which may enhance the role of the snack bar as an energy-providing product.

Dietary fiber content also differed significantly among treatments ($p < 0.05$) and demonstrated a clear tendency to increase with increasing proportions of Tahitian chestnut flour. Formulations containing higher levels of Tahitian chestnut flour resulted in greater fiber content, consistent with previous reports indicating that Tahitian chestnut flour contains relatively high levels of dietary fiber, influenced by processing conditions and particle size (Rahayu *et al*., 2024). In contrast, although cowpea seeds are known to be rich in dietary fiber, the fiber content of cowpea flour is generally lower due to dehulling and milling processes (Abebe & Alemayehu, 2022; Swaroopa, Agarkar, & Kshirsagar, 2025). This trend suggests that increasing the proportion of Tahitian chestnut flour plays a key role in enhancing the dietary fiber content of the snack bar, supporting the potential of these local ingredients to produce snack products with competitive fiber levels compared to commercial snack bar (Asriasih, Purbowati, & Anugrah, 2020).

Sensory Evaluation of Snack Bar

Sensory evaluation is an analytical approach that relies on human senses to determine consumer preferences toward food products. This method engages sight, smell, taste, and touch to assess attributes such as texture, appearance, aroma, and flavor (Hussain, 2020). Sensory evaluation of snack bar samples can be seen in Table 4.

Table 4- Sensory of snack bar

Parameters	A	B	C	D	E
Taste	3.55 ± 0.9[a]	3.77 ± 0.84[a]	3.55 ± 0.72[a]	3.74 ± 0.86[a]	3.55 ± 0.68[a]
Texture	3.71 ± 0.64[a]	3.81 ± 0.60[a]	3.71 ± 0.39[a]	3.90 ± 0.60[a]	3.77 ± 0.67[a]
Color	3.52 ± 0.85[a]	3.81 ± 1.14[a]	3.52 ± 0.77[a]	3.61 ± 0.84[a]	3.68 ± 0.83[a]
Aroma	3.32 ± 0.79[a]	3.45 ± 0.89[a]	3.77 ± 0.72[a]	3.29 ± 0.78[a]	3.48 ± 0.85[a]
Overall appearance	3.65 ± 0.75[a]	3.65 ± 0.80[a]	3.87 ± 0.56[a]	3.81 ± 0.75[a]	3.87 ± 0.76[a]

Expressed values were mean±SD (n = 31); a same row containing means with the same superscript letters are not significantly different ($p < 0.05$).
A: The ratio of Tahitian chestnut flour and cowpea flour (1:1)
B: The ratio of Tahitian chestnut flour and cowpea flour (1:5)
C: The ratio of Tahitian chestnut flour and cowpea flour (2:1)
D: The ratio of Tahitian chestnut flour and cowpea flour (1:2)
E: The ratio of Tahitian chestnut flour and cowpea flour (5:1)

The results of the ANOVA test indicated that variations in the proportion of Tahitian chestnut flour and cowpea flour did not produce significant differences ($p>0.05$) in any of the sensory parameters evaluated, which included taste, texture, color, aroma, and overall appearance. The mean hedonic scores given by panelists for taste ranged from 3.55 to 3.77 (liked), texture from 3.71 to 3.90 (liked), color from 3.52 to 3.81 (liked), aroma from 3.32 to 3.77 (liked), and overall appearance from 3.65 to 3.87 (liked). In general, the snack bar samples were well accepted by panelists, despite the absence of significant differences among treatments. Nevertheless, a tendency was observed in which increasing the proportion of cowpea flour led to a decline in panelist preference levels. This phenomenon may be associated with the presence of the characteristic beany flavor of cowpea, which is generally less favored by consumers. Several volatile compounds contributing to the development of this aroma include 3-methyl-1-butanol, 1-pentanol, 1-octen-3-ol, (E,E)-2,4-heptadienal, acetophenone, 1-octen-3-one, and 3-isopropyl-2-methoxypyrazine (Trindler, Annika Kopf-Bolanz, & Denkel, 2022). These findings are consistent with the study of (Ariviani, Sholihin, & Nastiti, 2021), who reported that increasing cowpea proportions in cereal products led to a decrease in sensory characteristics. However, in the present study, the incorporation of butter in the snack bar formulation played a role in masking the distinct aroma of cowpea, thereby enabling the product to be accepted with relatively good hedonic scores by the panelists.

Antioxidant and Microbiology Properties of Snack Bar

The antioxidant activity of the snack bar formulations, expressed as IC_{50} values, ranged from 8,410 to 11,733 µg/ml, with ANOVA results indicating significant differences ($p < 0.05$) among formulations containing different proportions of Tahitian chestnut and cowpea flours. Lower IC_{50} values indicate stronger antioxidant activity, and formulation E exhibited the highest antioxidant activity among the tested samples. This trend may be associated with the higher proportion of Tahitian chestnut flour, as Tahitian chestnut seeds have been reported to contain antioxidant-related compounds such as linoleic acid, ethyl linoleate, ethyl oleate, and homopterocarpine (Sukadana & Santi, 2015). However, despite these differences, the overall antioxidant activity of all snack bar formulations was categorized as very weak, as all IC_{50} values exceeded 200 µg/ml. These results suggest that while Tahitian chestnut proportion influenced antioxidant activity, the formulated snack bar should not be considered a strong source of antioxidants. It should be noted that the antioxidant activity observed in this study was relatively low, which is expected for a processed snack product rather than a concentrated plant extract. Therefore, antioxidant activity was not considered a primary functional attribute of the developed snack bar.

The total count (TC) of the snack bar samples did not differ significantly among formulations ($p > 0.05$), indicating that variations in the proportion of Tahitian chestnut flour and cowpea flour had no measurable effect on microbial load. This absence of a clear trend suggests that the microbial quality of the snack bar was primarily influenced by processing conditions rather than by differences in raw material composition. The baking process, conducted at 130 °C for 20 min, likely played a major role in reducing microbial populations across all treatments, resulting in comparable TC values (Maghfiroh *et al.*, 2021). Total count is commonly used as an indicator of overall product hygiene and potential shelf stability. The consistently low TC values observed in this study suggest that the developed snack bar possess satisfactory microbiological quality and are suitable for further product development and storage studies. However, additional evaluations, such as shelf-life testing under different storage conditions, would be necessary to fully assess long-term microbiological stability.

Table 5- Antioxidant and TPC of Snack Bar

Parameters	A	B	C	D	E
Antioxidant activity (µg/ml)	11,733 ± 115^{a}	11,253 ± 105^{b}	9,470 ± 100^{c}	11,640 ± 87^{a}	8410 ± 170^{d}
TPC (CFU/g)	4 x 10$^{3\ a}$	2.7 x 10^{3a}	3.3 x 10^{3a}	3.3 x 10^{3a}	3 x 10^{3a}

Expressed values were mean±SD (n = 3); a same row containing means with the same superscript letters are not significantly different ($p < 0.05$).
A: The ratio of Tahitian chestnut flour and cowpea flour (1:1)
B: The ratio of Tahitian chestnut flour and cowpea flour (1:5)
C: The ratio of Tahitian chestnut flour and cowpea flour (2:1)
D: The ratio of Tahitian chestnut flour and cowpea flour (1:2)
E: The ratio of Tahitian chestnut flour and cowpea flour (5:1)

The Best Treatments by Zeleny's Method

Using the Zeleny multi-criteria decision-making method, the optimal snack bar formulation was identified by integrating physicochemical properties, nutritional composition, sensory acceptance, antioxidant activity, and microbiological quality (Supplementary File 1). Formulation E, with a Tahitian chestnut to cowpea flour ratio of 5:1, was selected as the best treatment because it demonstrated the most balanced overall performance across the evaluated attributes rather than excelling in a single parameter. This formulation achieved a favorable balance between carbohydrate and protein contributions, with moderate textural characteristics appropriate for snack bar consumption. Sensory evaluation further confirmed that formulation E maintained good overall consumer acceptance. Although its antioxidant activity, expressed as IC_{50} values, was relatively weak in absolute terms, formulation E exhibited stronger antioxidant activity compared to the other treatments and also showed the highest dietary fiber content, which may contribute to its functional potential.

Limitation

Economic evaluation was beyond the scope of the present study, which primarily focused on formulation development and product quality assessment. Future studies should incorporate techno-economic and cost–benefit analyses to evaluate the feasibility of large-scale production and commercialization of snack bars formulated with Tahitian chestnut and cowpea flours. Although Tahitian chestnut flour is not yet widely produced at an industrial scale, the processing steps employed in this study (boiling, drying, milling, and sieving) are technically comparable to those used for other tuber and legume-based flours and can be adapted to small and medium-scale production systems. However, further development of raw material supply chains will be necessary to support sustainable industrial-scale application.

Conclusion

This study demonstrated that Tahitian chestnut and cowpea flours can be incorporated into snack bar formulation as alternative carbohydrate and protein sources, respectively, without compromising product quality. Variations in their proportions influenced nutritional and physicochemical characteristics, particularly protein and dietary fiber contents, while sensory acceptance and microbiological quality remained within acceptable ranges across all formulations. Using a multi-criteria decision approach, formulation E (Tahitian chestnut:cowpea ratio of 5:1) exhibited the most balanced quality profile, characterized by suitable texture for snack bar consumption, good consumer acceptance, relatively higher antioxidant activity among treatments, and the highest dietary fiber content, while maintaining microbiological safety. These findings suggest that Tahitian chestnut–cowpea composite flour has promising potential for the development of functional snack bars, although further studies addressing techno-economic feasibility are required.

Author Contribution

Nur Agustin Mardiana: Conceptualization, funding acquisition, methodology, data processing, and drafting of the manuscript. **Nur Aini Mahmudah**: Data curation, validation, review and editing of the manuscript.

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ویژگی‌های کیفی مخلوط آرد شاه بلوط تاهیتی (*Inocarpus fagifer*) و لوبیا چشم بلبلی (*Vigna unguiculata*) به‌عنوان مواد تشکیل‌دهنده در اسنک بار

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چکیده

تقاضای روزافزون برای محصولات میان وعده‌ای مناسب و متعادل از نظر تغذیه‌ای، فرصت‌هایی را برای استفاده از مواد اولیه محلی کم مصرف در توسعه محصولات غذایی ایجاد کرده است. این مطالعه با هدف توسعه اسنک بار با استفاده از آرد شاه بلوط تاهیتی (Inocarpus fagifer) و لوبیا چشم بلبلی (Vigna unguiculata) به‌عنوان مواد اولیه موجود در محل و ارزیابی ویژگی‌های فیزیکوشیمیایی، حسی، آنتی‌اکسیدانی و میکروبیولوژیکی آنها انجام شد. پنج فرمولاسیون با نسبت آرد شاه بلوط تاهیتی به لوبیا چشم بلبلی متفاوت[A = 1:1 ؛ B = 1:5؛ C = 2:1؛ D = 1:2؛ E = 5:1] با استفاده از یک طرح کاملاً تصادفی تهیه شدند. افزودن شاه بلوط تاهیتی و لوبیا چشم بلبلی به‌طور قابل توجهی ($p < 0.05$) بر چندین پارامتر فیزیکوشیمیایی، از جمله رنگ، بافت، رطوبت، فیبر غذایی، ترکیب درشت مغذی‌ها و خواص آنتی‌اکسیدانی تأثیر گذاشت، در حالی‌که محتوای خاکستر به‌طور قابل توجهی تحت تأثیر قرار نگرفت. ویژگی‌های حسی و کیفیت میکروبیولوژیکی به‌طور قابل توجهی تحت تأثیر قرار نگرفتند و همه فرمولاسیون‌ها معیارهای هدونیک و ایمنی قابل قبولی را برآورده کردند. بر اساس روش تصمیم‌گیری چندمعیاره زلنی، فرمولاسیون E (نسبت شاه بلوط تاهیتی: لوبیا چشم بلبلی ۵:۱) به‌عنوان متعادل‌ترین فرمولاسیون در بین فرمولاسیون‌های ارزیابی شده شناسایی شد. این یافته‌ها پتانسیل آرد شاه بلوط و لوبیا چشم بلبلی تاهیتی را برای توسعه اسنک بار نشان می‌دهد و اطلاعات پایه‌ای را برای استفاده بیشتر از مواد اولیه محلی در محصولات غذایی با ارزش افزوده فراهم می‌کند.

واژه‌های کلیدی: اسنک بار، شاه بلوط تاهیتی، کیفیت، لوبیا چشم بلبلی

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