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Acceptability and Nutrient Profile of Cocoa Fruit Peel-Based Cookies: Exploring a Functional Food Potential

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Abstract

Cocoa (*Theobroma cacao* L.) is a valuable agricultural commodity that can be developed into diverse products with high economic potential. This study aimed to evaluate the sensory acceptability and nutrient composition of cookies formulated with cocoa fruit peel (Theobroma cacao L.) as a functional ingredient. Cocoa peel flour and cookies were analyzed for macronutrients (protein, fat, carbohydrates, fiber) and micronutrients (minerals, vitamins, flavonoids). Sensory evaluation was conducted using a hedonic scale on color, aroma, texture, and taste among 40 semi-trained panelists. Results showed that all formulations were generally acceptable, with the 10% cocoa peel substitution achieving the highest preference. Statistical analysis indicated significant differences in color and taste ($p < 0.05$), while aroma and texture showed no significant variation. Nutritional analysis confirmed that cocoa peel flour and cookies contained essential nutrients, including protein (9.46-9.75%), fat (5.14-9.35%), carbohydrates (46.48-55.37%), vitamins C and E, minerals (Fe, Ca, Zn), and flavonoids, although antioxidant levels decreased after baking. These findings highlight cocoa peel's potential as a functional food ingredient, supporting sustainable utilization of cocoa by-products.

Keywords: Acceptability; Cocoa Fruit Peel; Cookies; Functional Food; Nutrient Composition.

Abbreviations: CKBK: Cocoa Fruit Peel-Based Cookies; KBK: Cocoa Fruit Peel Flour; CRD: Completely Randomized Design; SNI: Indonesian National Standard

INTRODUCTION

Cocoa (*Theobroma cacao L.*) is a valuable agricultural commodity that can be developed into diverse products with high economic potential. The cocoa fruit consists primarily of two components: the cocoa beans and the cocoa fruit peel. Cocoa beans are widely utilized for chocolate production, whereas the peel constitutes the largest portion of the fruit, accounting for approximately 52–76% of its total weight (Shahbandeh, 2025). During cocoa bean processing, a substantial amount of peel waste is generated—approximately 10 tons of cocoa fruit peel for every ton of dried cocoa beans (Statista Research Departement, 2025). Typically, this by-product is discarded and left to decompose in plantation areas, contributing little to economic value and posing environmental concerns due to potential pollution (Anoraga et al., 2024; Silva et al., 2024).

Given the presence of polyphenolic compounds in cocoa beans, it is plausible that similar bioactive components exist in cocoa fruit peel. Previous studies have confirmed that cocoa peel contains significant bioactive and nutritional compounds, including alkaloids, flavonoids, tannins, saponins, and triterpenoids (Amin et al., 2025; Soares & Oliveira, 2022). Furthermore, cocoa peel is rich in protein, carbohydrates, fiber, and flavonoids, which have potential applications in nutraceutical development (Okiyama et al., 2017; Sanchez et al., 2025; Tušek et al., 2024).

Utilizing cocoa peel as a primary ingredient in cookie production represents a promising alternative, considering its high fiber content and antioxidant properties (Rojo-Poveda et al., 2020; Soares & Oliveira, 2022). However, current utilization of cocoa fruit peel remains limited, primarily as animal feed (Sotelo-Coronado et al., 2025). Based on these considerations, this study aimed to evaluate the macro- and micronutrient composition and sensory acceptability of cookies formulated with cocoa fruit peel, thereby contributing to the development of functional foods and enhancing the economic value of cocoa by-products.

MATERIALS AND METHODS

Research Design

This study employed a completely randomized design (CRD) to evaluate the acceptability of cocoa fruit peel-based cookies (CKBK). Laboratory analyses were conducted at multiple facilities within Haluoleo University:

- Biomolecular Laboratory, Faculty of Mathematics and Natural Sciences: Moisture content and mineral analysis (iron, calcium, zinc, chromium, potassium).
- Nanoscience and Nanotechnology Laboratory: Determination of flavonoids, cholesterol, and vitamins A, C, and E.
- Integrated Laboratory: Analysis of ash, protein, fat, total carbohydrates, and crude fiber. Additionally, the Food Laboratory, Department of Nutrition, Polytechnic of the Ministry of Health, Kendari, was used for the acceptability test and glycemic index analysis.

This research adhered to ethical standards, with approval obtained from the Health Research Ethics Commission (KEPK) of the Regional Management of the Indonesian Association of Public Health Experts (IAKMI), Southeast Sulawesi Province. All panelists provided informed consent after reviewing the participant information sheet. Confidentiality of respondent data was maintained, and only aggregated results are reported.

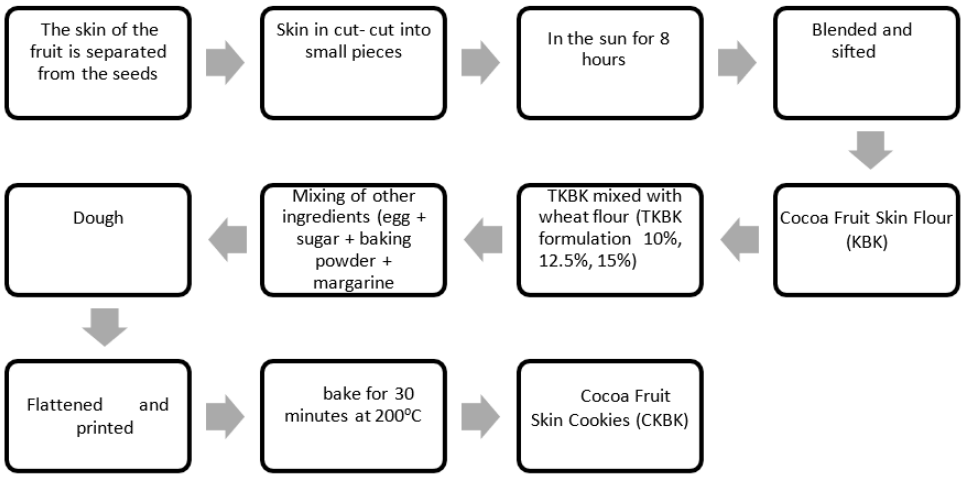

Figure 1. Flow of Making Flour and Cookies cocoa fruit peel (CKBK).

Materials

Cocoa Fruit Peel (Theobroma cacao L.)

Cocoa peels were sourced from Kolaka District, a major cocoa-producing region in Southeast Sulawesi. The peels were processed and analyzed for proximate composition and other nutritional parameters Cocoa Fruit Peel (*Theobroma cocoa* L.)

Acceptability Test Panelists

Forty semi-trained panelists, all students from the Department of Nutrition, participated in the sensory evaluation. Inclusion criteria included:

- Willingness to participate (confirmed by signed informed consent).
- Non-smoker.
- Free from illness (e.g., colds, throat or eye disorders) that could affect sensory perception.
- Not in a state of satiety or hunger during testing.

Cookie Formulation and Sensory Evaluation

Cookies were prepared with three levels of cocoa peel substitution: 10%, 12.5%, and 15%, with 100% wheat flour serving as the control. Each panelist evaluated four cookie samples for color, taste, aroma, and texture using a five-point hedonic scale (1 = very dislike, 5 = very like). Responses were recorded using a structured questionnaire.

Data analysis

Acceptability data were analyzed using the Friedman non-parametric test, following normality assessment with Kolmogorov-Smirnov and Shapiro-Wilk tests. Statistical analyses were performed using SPSS software, and results are presented in tables, graphs, and descriptive narratives.

RESULTS AND DISCUSSION

Macro and Micronutrients of KBK Flour and CKBK Cookies

Table 1. Results of Macro and Micro Analysis of KBK Flour and CKBK

Component	Unit	KBK Flour	CKBK Cookies
Macronutrients			
Moisture	%	0.87	4.3
Ash	%	8.36	2.32
Protein	%	9.46	9.75
Fat	%	5.14	9.35
Total Carbohydrates	%	46.48	55.37
Crude Fiber	%	2.03	1.52
Cholesterol	%	0.842	0.708
Micronutrients			
Vitamin C	Mg/100 G	0.075	0.097
Vitamin E	Mg/100 G	0.347	0.465
Iron (Fe)	Mg/Kg	1.02	1.08
Potassium (K)	Mg/Kg	0.87	4.3
Calcium (Ca)	Mg/Kg	23.7	22.5
Zinc (Zn)	Mg/Kg	1.22	1.53
Chromium (Cr)	Mg/Kg	<0.001	<0.001
Bioactive Compound			
Total Flavonoids	Mg/100 G	2.824	1.059

The table presents the nutrient profile of raw cocoa peel flour compared with the final cookie product. CKBK cookies showed higher moisture, fat, and total carbohydrate levels than KBK flour, while the KBK flour contained higher ash, crude fiber, and flavonoid content. Although some micronutrients such as potassium and zinc increased slightly in the processed product, others, such as calcium and flavonoids, showed reductions after baking.

The nutrient comparison between cocoa peel flour and cocoa–peel–based cookies indicate compositional changes associated with formulation and heat processing. Moisture content increased in the final product (4.30%) compared with the raw flour (0.87%), which is expected due to incorporation of wet ingredients during dough formation. Similarly, fat content increased nearly two-fold (5.14% to 9.35%), reflecting the addition of margarine during cookie preparation.

Total carbohydrates also increased from 46.48% in KBK flour to 55.37% in CKBK cookies, while protein content remained relatively stable (9.46% vs. 9.75%). In contrast, ash content and crude fiber were higher in the flour, suggesting some mineral dilution and partial fiber degradation during processing.

Micronutrient evaluation showed modest variation between the two samples. Zinc and potassium concentrations increased in the cookies, while calcium decreased slightly. Flavonoid content showed a reduction from 2.824 mg/100 g in KBK flour to 1.059 mg/100 g in CKBK cookies, which is consistent with thermal degradation of heat-sensitive phenolic compounds. Vitamins C and E increased slightly in the final cookies, which may be attributed to enrichment from added ingredients rather than retention from the peel flour.

Acceptability of CKBK Cookies

Table 2. Panelist Characteristics.

Characteristics	N (40)	%
Age (Years)		
18 – 20	28	70
21 – 23	12	30
Sex		
Male	3	7,5
Female	37	92,5
Religion		
Islam	37	92,5
Christianity	2	5
Catholic	1	2,5
Tribes		
Bugis	8	20
Tolaki	11	27,5
Muna	7	17,5
Buton	7	17,5
Toraja	2	5
Other	4	10

The majority of panelists (70%) were aged 18–20 years, and 92.5% were female. Most participants identified as Muslim (92.5%), with small proportions of Christianity (5%) and Catholicism (2.5%). Ethnic distribution was diverse, with Tolaki (27.5%) being the largest group, followed by Bugis (20%), and Muna and Buton (17.5% each). All panelists were students from the Department of Nutrition (D3 and D4 programs).

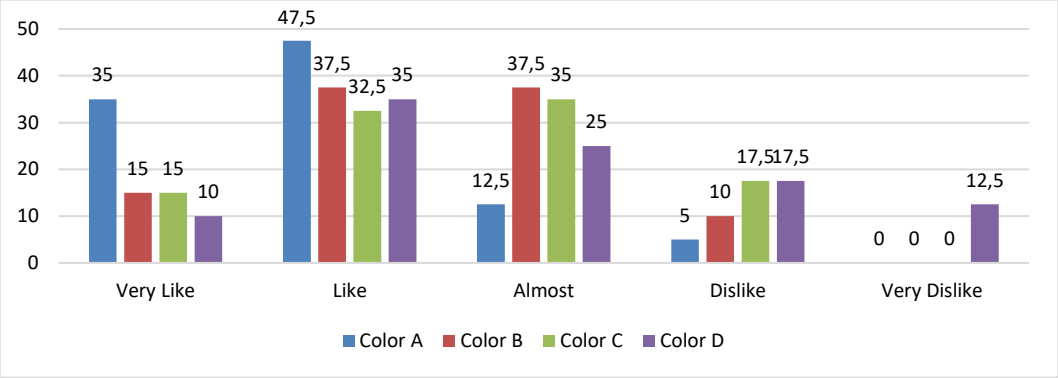

Figure 2. Acceptance Rate of CKBK Colors.

Figure 2 illustrates the panelists' preferences for cookie color across four formulations. The control sample (A) received the highest ratings, with 35% "very like" and 47.5% "like", indicating strong acceptance of its appearance. Cookies formulated with 10% cocoa peel (B) were the next most preferred. In contrast, cookies with 15% cocoa peel (D) were rated least attractive, with 12.5% of panelists marking "very dislike".

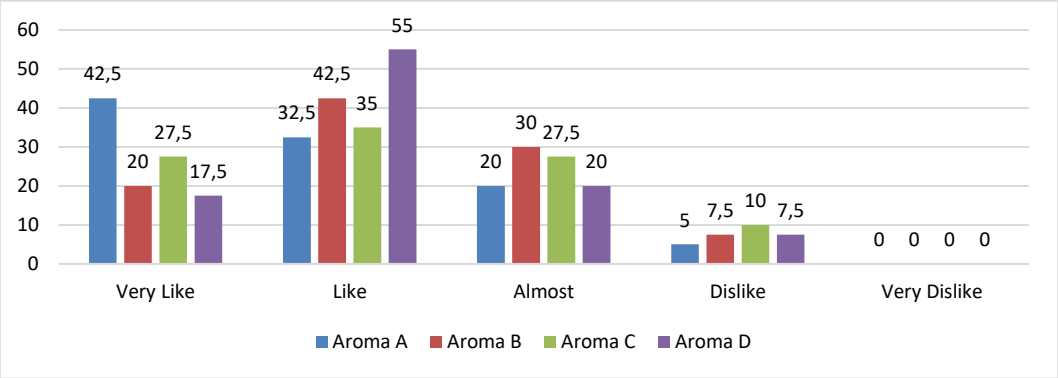

Figure 3. Acceptance Rate of CKBK Aroma.

Figure 3 shows panelists' preferences for cookie aroma across four formulations. The control sample (A) received the highest rating for "very like" (42.5%), indicating strong initial preference. However, in the "like" category, cookies with 15% cocoa peel (D) were most favored, with 55% of panelists selecting this option, followed by cookies B (10%) at 42.5%. Lower ratings were observed for cookies C (12.5%) in both categories. No panelists rated any sample as "very dislike".

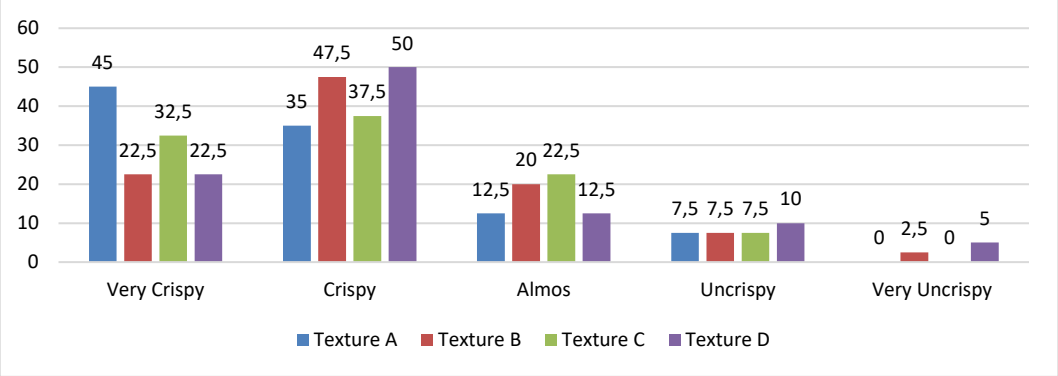

Figure 4. Acceptance Rate of CKBK Texture.

Figure 4 illustrates panelists' preferences for cookie texture across four formulations. The control sample (A) received the highest rating for "very crispy" (45%), indicating strong preference for its texture. However, in

the "crispy" category, cookies B (10% cocoa peel) were most favored (47.5%), followed closely by cookies D (15%) at 37.5%. A small proportion of panelists rated cookies B and D as "very uncrispy" (2.5% and 5%, respectively).

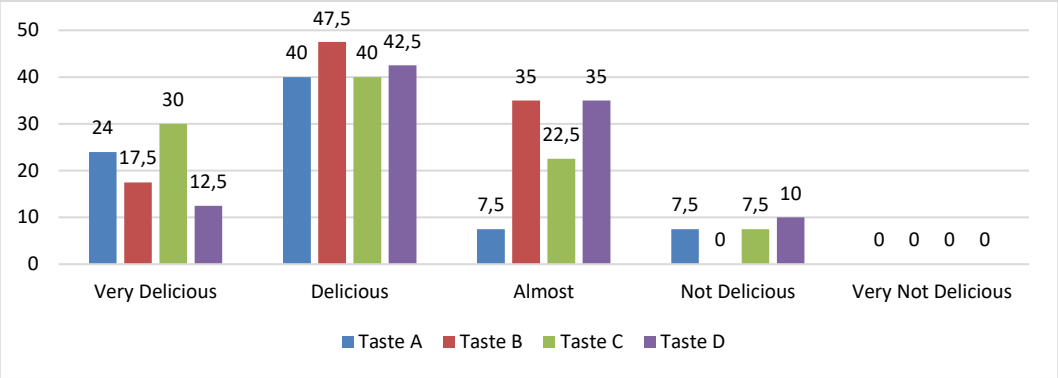

Figure 5. Acceptance Rate of CKBK Taste.

Figure 5 illustrates panelists' preferences for cookie taste across four formulations. The control sample (A) received the highest rating for "very delicious" (24%), followed by cookies B (10%) at 17.5% and cookies C (12.5%) at 12.5%. In the "delicious" category, cookies B (10%) were most favored (47.5%), closely followed by cookies D (15%) and cookies C (12.5%), both at 40%. A small proportion of panelists rated cookies as "not delicious," with cookies D receiving the highest negative rating (10%). No sample was rated as "very not delicious".

Table 3. Result of Data Normality Test and Difference in CKBK Acceptability.

Statistical Test	*P Value*			
	Color	**Aroma**	**Texture**	**Taste**
Kolmogorov-smirnov [a)]	0,000*	0,000*	0,000*	0,000*
Saphiro-Wilk [b)]	0,000*	0,000*	0,000*	0,000*
Friedman [c)]	0,000*	0,080	0,245	0,001*

[a) b)] Test the normality of the data. [c)] Nonparametric for RAL (ABCD Cookies). [*)] Significant < 0.05 (there is a difference)

Normality tests (Kolmogorov–Smirnov and Shapiro–Wilk) indicated that the acceptability data for all attributes (color, aroma, texture, taste) were not normally distributed ($p < 0.05$). Therefore, the Friedman test was applied to assess differences among treatments. Results showed significant differences in color ($p = 0.000$) and taste ($p = 0.001$) across the four cookie formulations, indicating that cocoa peel concentration influenced these attributes. Conversely, aroma ($p = 0.080$) and texture ($p = 0.245$) did not differ significantly among treatments

Discussion

Macro and Micronutrients of Cocoa Fruit Peel Flour and Cocoa Fruit Peel Cookies

The nutritional analysis included proximate composition (moisture, ash, protein, fat, carbohydrates, crude fiber, and cholesterol), selected micronutrients (vitamins and minerals), and bioactive flavonoids (Table 1). Moisture content influences textural quality and product stability, particularly crispness in cookies (Blahovec, 2007). The moisture content of KBK flour was relatively low (0.87%), whereas moisture increased to 4.30% in CKBK cookies, which may be attributable to the incorporation of additional ingredients and thermal processing.

The ash content of KBK flour (8.36%) was higher than that of the cookies (2.32%). Similar values have been reported in cocoa peel materials (5.9–13.0%) (Amin et al., 2025). The reduction in ash content following processing may relate to dilution by other ingredients or mineral losses during baking. Ash is commonly used as an indirect indicator of total mineral content, although it does not differentiate essential from non-essential minerals (Pomeranz & Meloan, 1994).

Protein levels were comparable between KBK flour (9.46%) and CKBK cookies (9.75%). Previous studies have reported protein levels of 2.1–9.1% in cocoa peels (Rojo-Poveda et al., 2020; Soares & Oliveira, 2022), indicating that the formulation of the cookies did not reduce protein content. Fat content increased from 5.14% in the flour to 9.35% in the cookies, likely due to the addition of egg yolk and margarine during preparation.

Fat contributes positively to texture and palatability in baked products (Drewnowski & Almiron-Roig, 2010).

Total carbohydrates were higher in CKBK cookies (55.37%) than in KBK flour (46.48%), consistent with the integration of other carbohydrate-containing ingredients. Similar carbohydrate ranges for cocoa peel have been documented (17.5–47.0%) (Djali et al., 2023). Crude fiber decreased after processing (from 2.03% to 1.52%), which may be due to particle size reduction and ingredient dilution. Although previous studies report much higher total dietary fiber content in cocoa peel (18–59%) (Arlorio et al., 2001), methodological differences and formulation effects may explain this variation. Cholesterol content was slightly lower in the cookies compared to the flour (0.842% vs. 0.708%), which is expected since cholesterol originates primarily from egg-based ingredients rather than the cocoa peel itself.

Micronutrient analysis indicated the presence of iron, zinc, potassium, and calcium in both samples, with minor variations following processing. These minerals play essential physiological roles, including oxygen transport, enzyme activity, nerve conduction, and cellular metabolism. However, the levels observed, particularly iron, were lower than commonly reported staple foods, suggesting that cookies are not a major mineral source.

The total flavonoid content of the cocoa peel flour was reduced after processing (from 2.824 to 1.059 mg/100 g). Thermal degradation may account for this decline, as flavonoids are sensitive to heat exposure (Lin & Choong, 2021). Despite the reduction, the presence of flavonoids indicates potential functional value, as cocoa-derived polyphenols have been associated with antioxidant capacity and metabolic modulation.

Acceptabililty of Cookies Cocoa Fruit Peel

The sensory evaluation results showed that all cookie formulations were generally well accepted by the panelists across parameters including color, aroma, texture, and taste. Among the tested formulations, the cookie formulation containing 10% cocoa peel flour substitution demonstrated the highest overall liking score. Sensory acceptance is influenced by visual, olfactory, textural, and flavor attributes, which collectively determine product acceptability (Ruiz-Capillas & Herrero, 2021).

Color was the first parameter evaluated, as visual perception plays a key role in consumer acceptance (Alba-Martínez et al., 2022). Statistical analysis indicated significant differences in color acceptability among formulations. All cocoa peel–based cookie formulations exhibited similar brown coloration, attributed to the incorporation of cocoa peel flour. This brown pigment likely results from the enzymatic oxidation of polyphenolic compounds by polyphenol oxidase, a reaction commonly observed in cocoa beans and peel tissue (Indiarto et al., 2023).

For aroma, panelists showed higher preference toward the control cookies (without cocoa peel flour) when scored on desirability; however, in the liking assessment, cookies containing the highest cocoa peel flour substitution received the most favorable ratings. Aroma perception is complex and highly subjective, and variability in panelist responses is consistent with the absence of standardized descriptors for many food odors (Pu et al., 2025; Rocha et al., 2022).

Taste, evaluated based on gustatory response, is recognized as the most influential factor affecting final consumer acceptance. Even when other attributes such as aroma, color, and texture are perceived positively, unfavorable taste may result in product rejection (Becker & Lawrence, 2025; Prinyawiwatkul, 2023). In this study, taste differences among formulations were influenced by the added cocoa peel flour, along with ingredients such as margarine, full-cream milk powder, and sugar.

Texture assessment was based on perceived crispness and breakability during consumption, including the formation of crumbs. Textural variation among formulations may be attributed to changes in gluten structure and water absorption capacity due to partial replacement of wheat flour with cocoa peel flour. As reported by Hong et al., (2025) reduced gluten content decreases water-binding capacity, resulting in lower moisture retention during baking and ultimately producing a crisper texture.

CONCLUSIONS

Cocoa fruit peel-based cookies were generally acceptable to panelists in terms of color, aroma, texture, and taste, with formulations containing 10% and 12.5% cocoa peel showing the highest preference. Significant differences were observed in color and taste acceptability, while aroma and texture remained consistent across formulations. Nutritional analysis confirmed that cocoa peel flour and cookies contain essential macronutrients and micronutrients, including protein (9.46–9.75%), fat (5.14–9.35%), carbohydrates (46.48–55.37%), vitamins C and E, minerals (Fe, Ca, Zn), and flavonoids, although antioxidant levels decreased after baking. These findings highlight cocoa peel's potential as a functional food ingredient, and future research should focus on optimizing formulations to enhance sensory quality and preserve bioactive compounds.

Authors' Contributions: Rita Irma designed the study. Rita Irma, Risma, Fonnie E. Hasan, Rosnah carried out the laboratory work. Risma, Fonnie E. Hasan analyzed the data. Rita Irma, Risma, Rosnah wrote the manuscript. All authors read and approved the final version of the manuscript.

Competing Interests: The authors declare that there are no competing interests.

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REFERENCES

Alba-Martínez, J., Sousa, P. M., Alcañiz, M., Cunha, L. M., Martínez-Monzó, J., & García-Segovia, P. (2022). Impact of context in visual evaluation of design pastry: Comparison of real and virtual. *Food Quality and Preference*, *97*, 104472. https://doi.org/10.1016/j.foodqual.2021.104472

Amin, I. I., Azis, H. A., & Mulyani, A. S. (2025). Extraction of Cocoa Fruit Skin Polyphenols by Soxhletation Method. *Jurnal Sains dan Teknologi*, 24–34.

Anoraga, S. B., Shamsudin, R., Hamzah, M. H., Sharif, S., & Saputro, A. D. (2024). Cocoa by-products: A comprehensive review on potential uses, waste management, and emerging green technologies for cocoa pod husk utilization. *Heliyon*, *10*(16), e35537. https://doi.org/10.1016/j.heliyon.2024.e35537

Arlorio, M., Coisson, J. d., Restani, P., & Martelli, A. (2001). Characterization of Pectins and Some Secondary Compounds from Theobroma cacao Hulls. *Journal of Food Science*, *66*(5), 653–656. https://doi.org/10.1111/j.1365-2621.2001.tb04616.x

Becker, E., & Lawrence, N. S. (2025). Disgust and distaste – Differential mechanisms for the rejection of plant- and animal-source foods. *Appetite*, *212*, 108033. https://doi.org/10.1016/j.appet.2025.108033

Blahovec, J. (2007). Role of water content in food and product texture. *International Agrophysics*, *21*(3), 209–215.

Djali, M., Santasa, K., Indiarto, R., Subroto, E., Fetriyuna, F., & Lembong, E. (2023). Proximate Composition and Bioactive Compounds of Cocoa Bean Shells as a By-Product from Cocoa Industries in Indonesia. *Foods*, *12*(17), 3316. https://doi.org/10.3390/foods12173316

Drewnowski, A., & Almiron-Roig, E. (2010). Human Perceptions and Preferences for Fat-Rich Foods. In J.-P. Montmayeur & J. le Coutre (Eds.), *Fat Detection: Taste, Texture, and Post Ingestive Effects*. CRC Press/Taylor & Francis. http://www.ncbi.nlm.nih.gov/books/NBK53528/

Indiarto, R., Reni, R., Utama, G. L., Subroto, E., Pangawikan, A. D., & Djali, M. (2023). The physicochemical, antioxidant, and sensory properties of chocolate biscuits incorporated with encapsulated mangosteen (*Garcinia mangostana* L.) peel extract. *International Journal of Food Properties*, *26*(1), 122–138. https://doi.org/10.1080/10942912.2022.2159429

Lin, Y. C., & Choong, Y. M. (2021). The Influence on Phenolic, Aroma Compounds, Rheological and Sensory Properties of Chocolates by Different Strains Inoculated Fermentation. *Journal of Food and Nutrition Research*, *9*(3), 124–135. https://doi.org/10.12691/jfnr-9-3-4

Okiyama, D. C. G., Navarro, S. L. B., & Rodrigues, C. E. C. (2017). Cocoa shell and its compounds: Applications in the food industry. *Trends in Food Science & Technology*, *63*, 103–112. https://doi.org/10.1016/j.tifs.2017.03.007

Pomeranz, Y., & Meloan, C. E. (1994). Ash and Minerals. In Y. Pomeranz & C. E. Meloan (Eds.), *Food Analysis: Theory and Practice* (pp. 602–624). Springer US. https://doi.org/10.1007/978-1-4615-6998-5_35

Prinyawiwatkul, W. (2023). Food-Evoked Emotion, Product Acceptance, Food Preference, Food Choice and Consumption: Some New Perspectives. *Foods*, *12*(11), 2095. https://doi.org/10.3390/foods12112095

Pu, D., Xu, Z., Sun, B., Wang, Y., Xu, J., & Zhang, Y. (2025). Advances in Food Aroma Analysis: Extraction, Separation, and Quantification Techniques. *Foods*, *14*(8), 1302. https://doi.org/10.3390/foods14081302

Rocha, S. M., Costa, C. P., & Martins, C. (2022). Aroma Clouds of Foods: A Step Forward to Unveil Food Aroma Complexity Using GC × GC. *Frontiers in Chemistry*, *10*, 820749. https://doi.org/10.3389/fchem.2022.820749

Rojo-Poveda, O., Barbosa-Pereira, L., Zeppa, G., & Stévigny, C. (2020). Cocoa Bean Shell—A By-Product with Nutritional Properties and Biofunctional Potential. *Nutrients*, *12*(4), 1123. https://doi.org/10.3390/nu12041123

Ruiz-Capillas, C., & Herrero, A. M. (2021). Sensory Analysis and Consumer Research in New Product Development. *Foods*, *10*(3), 582. https://doi.org/10.3390/foods10030582

Sanchez, P. D. C., Hashim, N., Basri, M. S. M., Saari, N. B., & Muhammad, D. R. A. (2025). Unlocking the potential of cacao bean shell as a functional food additive: Composition, applications, optimization, and future directions – a review. *Food Chemistry*, *492*, 145471. https://doi.org/10.1016/j.foodchem.2025.145471

Shahbandeh, M. (2025). *Cocoa industry—Statistics & facts*. Statista. https://www.statista.com/topics/3211/cocoa-industry/

Silva, J. M., Peyronel, F., Huang, Y., Boschetti, C. E., & Corradini, M. G. (2024). Extraction, Identification, and Quantification of Polyphenols from the Theobroma cacao L. Fruit: Yield vs. Environmental Friendliness. *Foods*, *13*(15), 2397. https://doi.org/10.3390/foods13152397

Soares, T. F., & Oliveira, M. B. P. P. (2022). Cocoa By-Products: Characterization of Bioactive Compounds and Beneficial Health Effects. *Molecules*, *27*(5), 1625. https://doi.org/10.3390/molecules27051625

Sotelo-Coronado, L. E., Oviedo-Argumedo, W., & Alvis-Bermúdez, A. (2025). Cacao in the Circular Economy: A Review on Innovations from Its By-Products. *Processes*, *13*(7), 2098. https://doi.org/10.3390/pr13072098

Statista Research Departement. (2025). *Global cocoa bean production from 2020/21 to 2023/24 with a forecast for 2024/2025, by country*. Statista. https://www.statista.com/statistics/263855/cocoa-bean-production-worldwide-by-region/

Tušek, K., Valinger, D., Jurina, T., Sokač Cvetnić, T., Gajdoš Kljusurić, J., & Benković, M. (2024). Bioactives in Cocoa: Novel Findings, Health Benefits, and Extraction Techniques. *Separations*, *11*(4), 128. https://doi.org/10.3390/separations11040128

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