JOURNAL OF INTERDISCIPLINARY PERSPECTIVES

ISSN Print: 2984-8288, ISSN Online: 2984-8385
Vol. 3 No. 12, pp. 315-324, December 2025

Valorization of Tropical Fruit Peels into Sustainable Food Crackers: Development, Utilization, and Consumer Acceptability

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Date received: November 2, 2025
Date revised: November 19, 2025
Date accepted: December 2, 2025

Originality: 89%
Grammarly Score: 99%
Similarity: 11%

Recommended citation:
Pelaje, R. M., Velasco, J. O., Elizon, J., Henson, O. N., Abay, I., Comendador, H., Dela Cruz, P. E., Divina, A. J., Junsay, M., Pallada, C. A. K., Villanada, J. C., & Aquino, R. (2025). Valorization of tropical fruit peels into sustainable food crackers: Development, utilization, and consumer acceptability. *Journal of Interdisciplinary Perspectives, 3*(12), 315-324. https://doi.org/10.69569/jip.2025.733

Abstract. This study explores the valorization of tropical fruit peels—specifically dragon fruit, durian, guyabano, jackfruit, marang, and pineapple—into sustainable food crackers through experimental development, laboratory testing, and sensory evaluation. The formulated crackers demonstrated positive phytochemical profiles, including flavonoids, phenols, and proteins, confirming their potential as functional food products. Microbiological analyses indicated compliance with safety standards, while proximate composition revealed desirable nutritional properties, including high carbohydrate content and moderate protein and fiber content. Sensory evaluation among faculty, students, and community respondents yielded an overall mean rating of 4.48 ("Like Extremely"), with texture and appearance rated highest. ANOVA results ($p = 0.037$) indicated significant differences among respondent groups, highlighting varying sensory preferences. The findings affirm that tropical fruit peel crackers are nutritionally beneficial, safe, and consumer-acceptable, offering a sustainable solution for waste reduction, food innovation, and environmental protection aligned with circular economy principles and the United Nations Sustainable Development Goals.

Keywords: Valorization; Tropical fruit peels; Sustainable food crackers; Consumer acceptability; Functional food; Circular economy; Food innovation

1.0 Introduction

The Philippines, a tropical archipelago rich in biodiversity, is among the leading producers of high-value fruits such as *Hylocereus undatus* (dragon fruit), *Durio zibethinus* (durian), *Annona muricata* (guyabano), *Artocarpus heterophyllus* (jackfruit), *Artocarpus odoratissimus* (marang), and *Ananas comosus* (pineapple). These fruits not only contribute to the country's agricultural economy and export potential but are also recognized for their nutritional and functional benefits. However, large volumes of their biomass, particularly the peels, are often discarded as agricultural waste. This disposal practice aggravates environmental burdens, including landfill accumulation and greenhouse gas emissions, while overlooking the potential of these materials as value-added resources (Sarker et al., 2024).

Fruit peels are rich sources of bioactive compounds, dietary fibers, vitamins, minerals, and natural pigments, making them promising raw materials for sustainable food innovation. Studies have shown that fruit residues can serve as excellent sources of nutraceuticals and functional ingredients, offering antioxidant, antimicrobial, and therapeutic properties (Bhardwaj et al., 2022). For instance, dragon fruit peels are rich in betacyanin and dietary fiber; durian peels contain polyphenols, flavonoids, and cellulose; guyabano peels are high in soluble and insoluble fibers; jackfruit peels provide pectin and phenolic compounds; marang peels exhibit biosorbent and antioxidant properties; and pineapple peels yield bromelain and vitamin C, which support digestive and immune health. The valorization of such bioactive-rich residues contributes to a circular economy model, reducing waste while simultaneously creating functional foods that enhance public health (Liu et al., 2023).

Despite these advantages, most existing studies emphasize the nutritional or biochemical profiling of single fruit peels or their limited applications in isolated product development. This leaves a critical knowledge gap regarding the synergistic benefits of combining multiple tropical fruit peels into a single formulation. Multi-peel integration may optimize functional properties, enrich nutritional content, and improve textural and sensory qualities, yet empirical research in this area remains scarce. Moreover, while food technology innovations have demonstrated the potential of waste valorization in controlled laboratory settings (Ahmed et al., 2009), there is insufficient evidence for translating these findings into commercially viable products that meet consumer expectations for taste, affordability, and cultural relevance (Chiaraluce et al., 2024). This gap highlights the need for research that combines scientific evaluation with consumer-oriented approaches.

In line with the United Nations Sustainable Development Goals (SDGs) particularly SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) valorizing fruit peels into nutritious and eco-friendly food products offers a pathway toward food security, sustainable agriculture, and reduced environmental impact (Galanakis, 2020). Furthermore, consumer-focused studies reveal a growing willingness to adopt upcycled and sustainable food products, provided that they demonstrate safety, quality, and palatability (Liechti et al., 2024).

Guided by these imperatives, this study seeks to transform the tropical fruit peels into sustainable food crackers. Specifically, it aims to develop innovative multi-fruit peel formulations; analyze their proximate composition and bioactive properties; evaluate consumer preferences and acceptability through sensory testing; and assess their potential market viability. By integrating laboratory experimentation with consumer insights, this research advances food waste valorization as a viable strategy for both environmental protection and economic development—ultimately bridging the gap between "waste reduction" and "food innovation."

2.0 Methodology

2.1 Research Design

This study employed an experimental research design to develop, utilize, and evaluate sustainable food crackers formulated from tropical fruit peels—specifically dragon fruit, durian, guyabano, jackfruit, marang, and pineapple. The experimental design was deemed most appropriate as it enabled the researchers to manipulate and control variables throughout the formulation, laboratory testing, and sensory evaluation phases. This approach enabled a systematic assessment of the developed product's nutritional composition, microbiological safety, and consumer acceptability. Furthermore, the design supported the study's aim of transforming fruit peel waste into a functional and sustainable food product, aligning with the principles of the circular economy and food innovation.

2.2 Participants and Sampling Technique

The study participants included 24 faculty members, 988 students, and 1,684 community residents from Metro Manila. The faculty and students were drawn from three programs: Bachelor of Science in Entrepreneurship, Bachelor of Science in Secondary Education major in Technology and Livelihood Education, and Bachelor of Science in Industrial Technology major in Food Technology. The study employed a purposive sampling technique, selecting respondents based on their familiarity and expertise in food product evaluation, food technology, and consumer behavior. This method ensured that participants could provide informed, relevant, and experience-based feedback regarding the sensory qualities of the developed sustainable food crackers.

2.3 Research Instrument

The instrument used for data collection was a sensory evaluation questionnaire adapted from the nine-point hedonic scale developed by Peryam and Pilgrim (1957) and modified into a five-point Likert scale. The instrument measured consumer acceptability across five sensory parameters: appearance, aroma, taste, texture, and overall quality. The scale included the following verbal equivalents: 5 – Like Extremely, 4 – Like Very Much, 3 – Neither Like nor Dislike, 2 – Dislike Very Much, and 1 – Dislike Extremely. The questionnaire underwent expert validation by three food science and nutrition specialists from the Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST) to ensure its clarity, appropriateness, and content validity.

A pilot test was conducted with 30 respondents (10 faculty, 10 students, and 10 community members) who were not part of the main study to assess the instrument's reliability. Using Cronbach's Alpha, the questionnaire's internal consistency was computed, yielding a reliability coefficient of 0.921, indicating excellent reliability according to George and Mallery (2003). This result confirmed that the instrument consistently measured consumers' sensory perceptions of the formulated tropical fruit peel crackers.

2.4 Data Gathering Procedure

The data gathering process consisted of three major phases. The first phase involved product formulation and development, during which the fruit peels were collected, cleaned, dried, and ground into fine powder. These were combined in varying proportions and used in the cracker formulation following standard baking protocols. The second phase was laboratory testing, during which the developed crackers underwent phytochemical, microbiological, and proximate composition analyses to determine their nutritional value, safety, and compliance with food quality standards, using AOAC and FDA reference methods. The final phase was the sensory evaluation, where the validated questionnaire was administered to the purposively selected participants. Each respondent evaluated the crackers based on appearance, aroma, taste, texture, and overall quality to determine consumer acceptability.

2.5 Data Analysis Procedure

The data gathered from the sensory evaluation and laboratory analyses were processed using descriptive and inferential statistical tools. The weighted mean was used to determine the level of consumer acceptability for each sensory attribute, while the standard deviation measured the degree of variability among responses. Cronbach's Alpha was employed during the pilot testing phase to establish the reliability of the sensory evaluation instrument. Descriptive analysis was also used to interpret the laboratory results, particularly the phytochemical, microbiological, and proximate composition data. All statistical computations were performed objectively to ensure accuracy, validity, and consistency in the interpretation of results.

2.6 Ethical Consideration

Before data collection, the researchers obtained institutional approval and informed participants about the study's purpose, procedures, and voluntary nature. Informed consent was obtained from all respondents, ensuring that participation was voluntary and that they could withdraw at any time without penalty. The confidentiality and anonymity of participants were strictly maintained throughout the study. Moreover, ethical standards in food handling, preparation, and sensory testing were observed to ensure the safety and well-being of all participants. Laboratory analyses were conducted in accredited facilities following proper hygiene and safety protocols to comply with ethical research and food safety guidelines.

3.0 Results and Discussion

3.1 Phytochemical Analysis of Tropical Fruit Peels

The phytochemical analysis of tropical fruit peels, including dragon fruit (*Hylocereus undatus*), durian (*Durio zibethinus*), guyabano (*Annona muricata*), jackfruit (*Artocarpus heterophyllus*), marang (*Artocarpus odoratissimus*), and pineapple (*Ananas comosus*), confirmed the presence of multiple bioactive compounds, namely flavonoids, tannins, phenols, coumarins, quinones, proteins, and simple sugars. These compounds collectively enhance the nutritional, functional, and sensory properties of the developed sustainable food crackers, while simultaneously contributing to health-promoting effects for consumers.

Flavonoids and phenols were abundant in all peel samples, consistent with earlier findings that fruit by-products are rich in polyphenols (Suleria et al., 2020). These compounds exhibit strong antioxidant activities, scavenging free radicals that may otherwise cause lipid oxidation in baked products. Their incorporation not only improves

the shelf stability of crackers but also enhances their role as functional foods with potential benefits in reducing the risk of chronic diseases, including cardiovascular ailments and diabetes. As noted by Hussain et al. (2023), fruit peels represent an underutilized reservoir of nutraceuticals, aligning with the growing demand for bioactive-enriched snacks in functional food markets.

Table 1. *Result of Analysis on the Phytochemical Analysis of Tropical Fruit Peels*

Analytes / Parameters	Results	Method
Extraction (Ethanol)	51g	Maceration / Distillation
Flavonoids	Positive	Sodium Hydroxide Test
Alkaloids	Negative	Dragendorff's Test
Saponins	Negative	Froth Test
Tannins	Positive	Ferric Chloride Test
Phenols	Positive	Ferric Chloride Test (Phenyl Hydroxy Group)
Anthocyanin	Negative	Colorimetric Test
Xanthoprotein	Positive	Ammonia Test
Terpenoids	Negative	Acid Anhydride Test
Glucose	Negative	Reducing Sugar Test
Polysaccharides	Negative	Iodine Test
Glycosides	Negative	Keller-Killani Test
Cardenolides	Positive	Keller-Killani Test
Oils	Negative	Stain Test
Monosaccharides	Positive	Barfoed's Test
Steroids	Negative	Acid Anhydride Test
Ketose	Positive	Seliwanoff's Test
Aldose	Negative	Seliwanoff's Test
Protein	Positive	Biuret Test
Coumarin	Positive	Alcoholic Sodium Hydroxide Test
Quinone	Positive	Sodium Hydroxide Test

Tannins, though often classified as anti-nutrients, were also identified in moderate amounts. Their dual role as both natural antioxidants and antimicrobials is critical in improving the safety and shelf life of the crackers. Zayed et al. (2025) emphasized that tannins inhibit microbial growth and oxidative rancidity, while Lopes et al. (2023) demonstrated their effectiveness when applied in plant-based coatings for perishable foods. In the present study, the controlled levels of tannins in the crackers likely contributed to subtle flavor complexity without imparting undesirable astringency, thus striking a balance between nutritional functionality and consumer acceptability.

The presence of proteins, confirmed through Biuret and xanthoprotein tests, adds both nutritional and technological value. Proteins provide essential amino acids for dietary requirements and also contribute to emulsification, foaming, and water-binding capacity, thereby enhancing the dough structure and the textural crispness of the crackers. These findings agree with Day et al. (2022), who underscored the rising importance of plant proteins in bakery applications, and with Wu (2013), who highlighted the role of functional amino acids in human metabolic health. Therefore, peel-derived proteins contribute beyond mere nutrition, integrating health, structure, and functionality into the final product.

Monosaccharides and ketose sugars, such as glucose and fructose, were also present. These compounds serve as key contributors to energy value, sweetness, and palatability. More importantly, during baking, they participate in the Maillard reaction with amino acids, generating melanoidins that impart the crackers' characteristic golden-brown color, roasted aroma, and enhanced flavor (Damodaran & Parkin, 2017). The sensory improvements resulting from these reactions are crucial for consumer acceptance, especially in markets where taste and appearance remain strong drivers of purchase decisions.

Interestingly, the analysis also noted the absence of alkaloids, saponins, terpenoids, anthocyanins, and oils. This absence is advantageous for product development, as these compounds are often associated with bitterness, instability, or off-flavors (El Omari et al., 2021). Moreover, the absence of oils reduces the risk of lipid oxidation and rancidity, thereby prolonging the shelf life of the crackers. This phytochemical profile ensures a palatable, safe, and storage-stable product suitable for broader market utilization.

Overall, the phytochemical composition of the evaluated fruit peels highlights their potential for valorization as sustainable ingredients in food systems. The synergistic interactions between antioxidants (flavonoids, phenolics,

tannins), proteins, and sugars not only enhance the nutritional density and functional properties of the crackers but also support consumer health and product appeal. These findings reinforce the arguments of Bhardwaj et al. (2022) that fruit and vegetable peels represent a valuable resource for functional food development, especially for reducing food waste and advancing sustainability goals.

3.2 Microbiological Analysis of Formulated Sustainable Food Crackers from Tropical Fruit Peels

The microbiological analysis of formulated crackers enriched with tropical fruit peels was conducted to assess food safety and compliance with international standards of hygienic food production. Ensuring microbiological safety is critical for novel food products derived from agricultural by-products, as these substrates may carry microbial contaminants if not properly processed (Julien-Javaux et al., 2019).

Table 2. *Result of Analysis on the Microbiological Analysis of Formulated Sustainable Food Crackers from Tropical Fruit Peels*

Microbiological Parameters	Results	Reference Method
Total Coliform Count (MPN/g)	< 3.0	FDA BAM – 4, 2020 (MPN Method)
E.coli Count (MPN/g)	< 3.0	FDA BAM – 4, 2020 (MPN Method)
Listeria spp. Detection (per 25g)	Negative	ISO 11290 – 1:2017 (Conventional Method)
Salmonella spp. Detection (per 25g)	Negative	FDA BAM – 5, 2024 (Conventional Method)

The results indicated that the Total Coliform Count (MPN/g) and Escherichia coli Count (MPN/g), measured using the FDA Bacteriological Analytical Manual (BAM) reference method for coliforms (Feng et al., 2020), were both <3.0 MPN/g. This finding demonstrates that the formulated crackers fell well below the acceptable threshold for microbial contamination, reflecting both the effectiveness of thermal processing during baking and proper hygienic handling.

For pathogenic bacteria, Listeria spp. Detection (per 25 g sample) was performed following ISO 11290-1:2017, a globally recognized standard for *Listeria* detection in food products (International Organization for Standardization, 2017). The samples tested negative, which is significant since *Listeria monocytogenes* is a major foodborne pathogen associated with ready-to-eat foods (Hitchins et al., 2022)—similarly, Salmonella spp. Detection (per 25 g sample), conducted according to FDA BAM Chapter 5 (Andrews et al., 2024), also yielded negative results. The absence of *Salmonella* is essential for ensuring consumer protection, as this pathogen remains one of the leading causes of global foodborne illness outbreaks.

These microbiological results confirm that the developed fruit peel–based crackers meet international food safety standards. According to Codex Alimentarius guidelines (FAO & WHO, 2023), foods intended for direct consumption must be free from *Salmonella* and *Listeria monocytogenes*, while maintaining coliform and *E. coli* counts at levels that reflect good hygienic practices. The findings from this study align with these requirements, suggesting that valorizing fruit peels into crackers not only provides nutritional and functional benefits but also ensures consumer acceptability and safety.

The negative results for pathogenic microorganisms can also be attributed to the bioactive compounds naturally present in tropical fruit peels, such as polyphenols, tannins, and flavonoids, which exhibit antimicrobial properties (Chel-Guerrero et al., 2022). Previous studies have shown that extracts from fruit peels can inhibit microbial growth, further supporting their role in enhancing food safety (Chaiwarit et al., 2021). This dual function—improving nutritional quality while providing antimicrobial protection—strengthens the potential of fruit peels as sustainable food ingredients.

Overall, valorizing fruit peel waste into safe and functional food products contributes to advancing circular economy practices and reducing agro-industrial waste (Papag, 2025). By transforming potential waste into consumer-acceptable products that meet stringent microbiological standards, the study demonstrates a viable pathway toward waste-to-wealth initiatives in alignment with both food safety and environmental sustainability goals.

3.3 Proximate Composition Analysis of Formulated Sustainable Food Crackers from Tropical Fruit Peels

The proximate composition analysis of the formulated sustainable food crackers derived from tropical fruit peels—dragon fruit (*Hylocereus undatus*), durian (*Durio zibethinus*), guyabano (*Annona muricata*), jackfruit (*Artocarpus heterophyllus*), marang (*Artocarpus odoratissimus*), and pineapple (*Ananas comosus*)—demonstrated promising nutritional and functional potential. The proximate analysis revealed the following composition:

moisture content (3.9%), total fat (31.6%), ash (3.8%), energy (527 kcal), total carbohydrates (55.5%), protein (5.2%), total dietary fiber (3.8%), sodium (1220 mg), and saturated fat (13.5%), while total sugars (fructose, glucose, sucrose, maltose, and lactose) were not detected.

Table 3. *Result of Analysis on the Proximate Analysis of Formulated Sustainable Food Crackers from Tropical Fruit Peels*

Analyte per 100g	Results	Reference Method
Moisture*, g	3.9	AOAC 925.09
Total Fat*, g	31.6	Solvent Extraction (Soxhlet) with Acid Hydrolysis
Ash*, g	3.8	AOAC 923.03
Energy*, kcal	527	Computation Atwater Factor
Total Carbohydrates*, g	55.5	Computation, By Difference
Protein* (N x 6.25), g	5.2	Automated Kjeldahl Method
Total Dietary Fiber, g	3.8	AOAC 991.43 (Method)
Sodium, mg	1220	AOAC 999.10 (Modified)
Total Sugars*, g	**Not Detected**	In-house Developed HPLC Method, CHE-AM-011
Fructose*, g	**Not Detected** Limit of Detection =1.0223 mg/mL	In-house Developed HPLC Method, CHE-AM-011
Glucose*, g	**Not Detected** Limit of Detection =1.0636 mg/mL	In-house Developed HPLC Method, CHE-AM-011
Sucrose*, g	**Not Detected** Limit of Detection =1.0326 mg/mL	In-house Developed HPLC Method, CHE-AM-011
Maltose*, g	**Not Detected** Limit of Detection =1.0759 mg/mL	In-house Developed HPLC Method, CHE-AM-011
Lactose*, g	**Not Detected** Limit of Detection =1.0666 mg/mL	In-house Developed HPLC Method, CHE-AM-011
Saturated Fat, g	13.5	AOAC 996.06/WHO Global Protocol (Modified)

These results indicate that the crackers have a low moisture content, which is advantageous for extended shelf stability and crispness, a finding consistent with that of Mala et al. (2024), who reported similar physicochemical stability in pineapple peel-based crackers due to their low water activity. The moderate ash and dietary fiber contents highlight the mineral and fiber-enriched composition of the product, attributable to the natural constituents of fruit peels such as cellulose, hemicellulose, and lignin (El-Beltagi et al., 2023). These components contribute not only to the nutritional enhancement but also to the textural and functional quality of baked products.

The protein content (5.2%) reflects the nutritional contribution of fruit peel residues, particularly from jackfruit and guyabano, which are known for their amino acid and polyphenolic content (Trejo Rodríguez et al., 2021). Likewise, the fat content (31.6%) suggests that the crackers contain natural lipid fractions that enhance flavor and palatability. This aligns with findings by Mousa et al. (2021), who observed improved mouthfeel and sensory satisfaction in snack crackers enriched with plant-based by-products. However, the high sodium level (1220 mg) may require optimization to comply with recommended dietary limits, balancing taste enhancement with health considerations.

From a functional food perspective, tropical fruit peels are recognized for their abundance of bioactive compounds, including polyphenols, flavonoids, and carotenoids, which offer antioxidant and antimicrobial properties (Le, 2022). For instance, dragon fruit peel contributes betacyanin and phenolic compounds that enhance the antioxidant potential of bakery products (Chumroenvidhayakul et al., 2023). Similarly, durian and pineapple peels have been documented as rich sources of dietary fiber, vitamin C, and bioactive metabolites that support digestive health and help reduce oxidative stress (Khaksar et al., 2024).

The valorization of these peels in food systems demonstrates a dual benefit of waste minimization and nutritional enhancement, consistent with the sustainable food innovation approach outlined by Gallardo et al. (2025). Their research on pumpkin industry by-products showed that incorporating vegetable waste in cracker formulations significantly improved nutritional profiles while maintaining consumer acceptability. Likewise, Martin-Diana et al. (2016) found that carob seed peels enhanced antioxidant activity in gluten-free crackers without compromising sensory quality—an outcome mirrored in the current study's favorable proximate composition.

Consumer acceptability of fruit peel–based food products is closely linked to awareness of their health benefits and environmental sustainability. Onyenweaku et al. (2022) emphasized that consumers increasingly favor value-added products formulated from fruit by-products when their nutritional benefits are communicated effectively.

Furthermore, Onyenweaku et al. (2025) revealed that blends of fruit peel additives improved nutritional content and were perceived as healthy and eco-friendly alternatives, aligning with the sustainability objectives of this study.

Comparable studies on the utilization of fruit peel in snack and bakery products also report that integrating peel powder enhances texture, color, and antioxidant activity, contributing to a functional and appealing product (Ismail et al., 2024). The use of marang and jackfruit peels, though less commonly reported, follows the same valorization pathway described by Sarangi et al. (2023), emphasizing zero-waste food innovation and the transformation of agro-industrial residues into nutritionally rich components.

Overall, the developed tropical fruit peel crackers exemplify a sustainable, nutrient-dense, and consumer-acceptable food innovation, reinforcing the circular economy approach in the food industry. The findings align with global valorization efforts that emphasize the use of fruit by-products as functional food ingredients to promote environmental sustainability and public health (Nirmal et al., 2023).

The proximate composition findings underscore the feasibility of fruit peel valorization for functional food formulation, offering an eco-friendly pathway to manage food waste while developing marketable, health-oriented snack products. The integration of tropical fruit peels aligns with the United Nations Sustainable Development Goals (SDGs), particularly those promoting responsible consumption and production. Future studies may further optimize formulation parameters to enhance nutrient bioavailability, reduce sodium content, and evaluate long-term consumer acceptance across demographic groups.

3.4 Consumer Acceptability using Sensory Evaluation

The consumer acceptability of the formulated sustainable food crackers developed from tropical fruit peels—specifically dragon fruit, durian, guyabano, jackfruit, marang, and pineapple—was assessed through sensory evaluation using parameters such as appearance, aroma, taste, texture, and overall quality. The overall weighted mean rating of 4.48, interpreted as *Like Extremely*, indicates a highly favorable consumer perception of the product's sensory attributes, suggesting its potential for market acceptance as a sustainable, nutritious snack alternative.

Table 4. *Respondents' Assessment of Formulated Sustainable Food Crackers from Tropical Fruit Peels*

Criteria	Faculty		Student		Community		Overall	
	WM	VI	WM	VI	WM	VI	WM	VI
1. Appearance	4.50	LE	4.68	LE	4.37	LE	4.52	LE
2. Aroma	4.33	LE	4.54	LE	4.30	LE	4.39	LE
3. Taste	4.46	LE	4.56	LE	4.37	LE	4.46	LE
4. Texture	4.67	LE	4.66	LE	4.48	LE	4.60	LE
5. Overall Quality	4.25	LE	4.53	LE	4.46	LE	4.41	LE
Overall Weighted Mean	4.44	LE	4.59	LE	4.40	LE	4.48	LE

Legend:	Range	Scale	Verbal Interpretation	Symbol
	5	4.20-5.00	Like Extremely	LE
	4	3.40-4.19	Like Very Much	LVM
	3	2.60-3.39	Neither Like nor Dislike	NLD
	2	1.80-2.59	Dislike Very Much	DVM
	1	1.00-1.79	Dislike Extremely	DE

Among the sensory parameters, texture (4.60) received the highest mean score, suggesting that the crispness and mouthfeel of the crackers were key contributors to consumer satisfaction. This finding aligns with Taştan's (2023) study, which emphasized that sensory attributes, particularly texture, play a critical role in consumer liking and purchase intent for fiber-enriched or upcycled fruit-based snacks. Similarly, the high rating for appearance (4.52) underscores the importance of visual appeal in food selection, a factor Tuorila (2015) noted as central to consumer sensory response and preference formation.

When analyzed by respondent category, the results showed consistently high acceptance across all groups. Faculty respondents from the Bachelor of Science in Entrepreneurship, Bachelor of Science in Secondary Education major in Technology and Livelihood Education, and Bachelor of Science in Industrial Technology, primarily in Food Technology programs, provided an overall weighted mean of 4.44, with texture (4.67) rated highest and aroma (4.33) rated lowest. The student respondents gave an even higher overall mean of 4.59, strongly favoring appearance (4.68) and texture (4.66). At the same time, community respondents outside the academic setting also expressed high satisfaction with an overall mean of 4.40, citing texture (4.66) and taste (4.48) as the most appealing

qualities.

These findings confirm that upcycled food products derived from fruit peels can achieve strong sensory and consumer acceptance, supporting the growing movement toward waste valorization and sustainable food innovation. According to Nirmal et al. (2023), fruit peels are rich in bioactive compounds, antioxidants, and dietary fiber, thereby enhancing nutritional quality and improving sensory characteristics, such as flavor and texture, when incorporated into food formulations. This suggests that the functional compounds present in tropical fruit peels may have contributed to the desirable organoleptic qualities observed in the crackers.

Furthermore, the high level of consumer approval supports the feasibility of utilizing fruit by-products in functional food development, consistent with the findings of Lau et al. (2021), who demonstrated that fruit and vegetable by-products can be effectively integrated into food systems to improve health benefits while reducing food waste. Galanakis (2020) also highlighted that food waste valorization presents economic and environmental opportunities by transforming by-products into value-added food ingredients—a principle clearly reflected in the development of these sustainable fruit peel crackers.

The favorable consumer response resonates with the arguments of Chang et al. (2024), who emphasized that consumer acceptance of upcycled or functional food products depends on their perceived quality, sensory appeal, and alignment with health and environmental values. Moreover, Ye (2023) noted that sustainable marketing of upcycled foods can leverage sensory satisfaction and eco-conscious narratives to attract modern consumers seeking wellness-oriented and environmentally responsible choices.

Overall, the results of the sensory evaluation affirm that tropical fruit peels can be effectively valorized into high-quality, consumer-acceptable food products. This aligns with Silvestri et al. (2024), who advocated for reimagining food waste as a resource within a circular economy framework. The findings thus contribute to ongoing global efforts to reduce food waste while promoting innovation in sustainable food production.

3.5 Comparative Assessment

The analysis revealed that the computed p-value (0.037) is less than the established significance level ($\alpha = 0.05$), indicating a statistically significant difference among the three groups of respondents—faculty members, students, and community participants—in their evaluations of the formulated sustainable food crackers. This finding implies that although all groups generally rated the product favorably, with an overall interpretation of "Like Extremely," their assessments varied in degree.

Table 5. *Comparative Assessment on the Consumer Acceptability of Formulated Sustainable Food Crackers from Tropical Fruit Peels*

Criteria	F-value	p-value	Interpretation
Appearance	4.39	0.037	Significant
Aroma	4.39	0.037	Significant
Taste	4.39	0.037	Significant
Texture	4.39	0.037	Significant
Overall Quality	4.39	0.037	Significant

The observed variation suggests differences in sensory preferences, taste perception, or acceptability standards among the groups. Specifically, students had the highest mean rating (4.59), followed by faculty members (4.44) and community respondents (4.40). These differences may be attributed to factors such as age, exposure to experimental food products, and openness to innovative food formulations, which could influence individual perceptions of taste, texture, and overall product quality.

4.0 Conclusion

Based on the study's findings, several conclusions can be drawn about the valorization of tropical fruit peels into sustainable food crackers. The phytochemical evaluation of tropical fruit peels (dragon fruit, durian, guyabano, jackfruit, marang, and pineapple) confirmed the presence of multiple bioactive compounds—flavonoids, tannins, phenols, coumarins, quinones, proteins, and monosaccharides. These compounds enrich the crackers with antioxidant, antimicrobial, and nutritional benefits. The absence of undesirable compounds (e.g., alkaloids, oils, terpenoids) ensured safety and palatability. The results affirm that fruit peels are valuable sources of natural functional ingredients that can enhance the health-promoting properties, stability, and market potential of food

products.

The formulated crackers met international microbiological safety standards. Total coliform and *E. coli* counts were <3.0 MPN/g, while *Listeria spp.* and *Salmonella spp.* were undetected, confirming the product's safety and hygienic preparation. These findings demonstrate the effectiveness of thermal processing and the antimicrobial properties of the natural phytochemicals present in fruit peels. The results reinforce the potential of fruit peel valorization within sustainable, food-safe production frameworks that support waste-to-wealth initiatives.

Proximate results indicated that the crackers contained low moisture (3.9%), moderate ash (3.8%), high total fat (31.6%), and carbohydrates (55.5%), with energy at 527 kcal per 100 g. Protein (5.2%) and dietary fiber (3.8%) levels were of good nutritional value, though the sodium content (1220 mg) may need to be optimized. These findings demonstrate that tropical fruit peel–based crackers are nutrient-dense and shelf-stable. They offer functional benefits from their fiber, protein, and phenolic content, aligning with sustainable nutrition and circular economy principles.

Sensory evaluation results showed a high overall weighted mean of 4.48 (Like Extremely**)**, with texture and appearance receiving the highest scores. Faculty, students, and community respondents all expressed strong approval, confirming broad consumer acceptance. The results demonstrate that sustainable snack innovations derived from fruit by-products can satisfy sensory expectations while promoting environmental responsibility and waste reduction.

There is a significant difference in consumer acceptability ratings among faculty, students, and community respondents across all sensory parameters (appearance, aroma, taste, texture, and overall quality). These findings suggest that demographic or experiential factors may influence sensory preferences for upcycled food products, such as tropical fruit peel crackers.

5.0 Contributions of Authors

None declared.

6.0 Funding

None declared.

7.0 Conflict of Interests

None declared.

8.0 Acknowledgment

None declared.

9.0 References

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