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Research Article

Sensory evaluation of Cebu's chips using Cassava (*Manihot esculenta*) flour infused with fresh blended Malunggay (*Moringa oleifera*) leaves

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Abstract

Cassava *(Manihot esculenta)* and malunggay *(Moringa oleifera)* are widely cultivated in the Philippines and valued for their nutritional and health benefits. Cassava is a major source of carbohydrates and dietary fiber, while malunggay is rich in vitamins, minerals, and antioxidants. This study aimed to develop and evaluate cassava flour chips infused with fresh blended malunggay leaves as a functional, locally sourced snack that may help combat malnutrition. Three chip formulations containing different concentrations of malunggay leaves (¼ cup, ½ cup, and ¾ cup) were prepared. Sensory evaluation was conducted with 30 food experts and 70 consumer panelists, using a 5-point hedonic scale to assess aroma, color, taste, and texture. Data were analyzed using analysis of variance (ANOVA). Results showed that all formulations were generally acceptable, but F_1 (¼ cup malunggay) obtained the highest overall scores (aroma = 3.91 ± 0.86, color = 3.70 ± 0.94, taste = 4.00 ± 0.82, texture = 3.85 ± 0.89). Significant differences ($p < 0.05$) were observed among formulations in taste and texture, indicating that higher malunggay content slightly reduced acceptability. The study demonstrates the novelty of integrating malunggay into cassava-based snack products, providing both enhanced nutritional value and consumer acceptability. This work highlights the potential of cassava–malunggay chips as an affordable, nutritious, and sustainable food innovation that can support public health and local agricultural development.

Keywords: Analysis of variance (ANOVA), Manihot esculenta, Moringa oleifera, Sensory Evaluation

INTRODUCTION

Malnutrition, a preventable crisis, continues to weaken health, hinder development, and diminish quality of life. In 2022, the World Health Organization (WHO) reported that approximately 149 million children under five were stunted, 45 million wasted, and 37 million overweight or obese. The double burden of malnutrition is now a global concern (Santos *et al*., 2023). In the Philippines, childhood stunting remains high, with 28.8% of children under five stunted, 5.5% wasted, and 1.5 million suffering from anemia (Reyes and Delos Reyes, 2024; Wabe *et al*., 2024). These deficiencies impair children's physical and cognitive development, increase vulnerability to infections, and hinder educational and economic progress.

To address these issues, government initiatives such as the Philippine Multisectoral Nutrition Project and the National Feeding Program aim to expand access to nutrition and health services (Reyes and Delos Reyes, 2024; Wabe *et al*., 2024). School feeding programs that integrate local produce further improve diet quality and sustainability (Batistela dos Santos *et al*., 2022). By linking local agriculture with nutrition, these programs support farmers, reduce environmental impact, and promote healthier, culturally appropriate meals.

Agriculture remains central to food security and livelihoods in the Philippines. Key crops include rice, corn, coconut, sugarcane, banana, and root crops like cassava. Malunggay (*Moringa oleifera),* valued for its resilience and nutritional profile, is widely used in both rural and urban diets. It provides high levels of protein, vitamins, minerals, and antioxidants, and supports the management of chronic diseases (Peñalver *et al*., 2022; Abdalla *et al*., 2022; Mthiyane, 2022; Phimarn *et al*, 2021; Islam, 2021). Cassava (*Manihot esculenta),* another vital crop, feeds over 800 million people globally and is rich in carbohydrates, vitamin C, and essential minerals, further underscoring its role in sustainable food systems (Bayata, 2019; Sengar, 2022).

Despite their potential, cassava and malunggay remain underutilized in value-added food products (Aafesse Shirko, 2021). Both are integral to traditional diets, yet their commercialization faces challenges due to limited product innovation. Unhealthy snack foods, particularly chips, are popular but criticized for their poor nutritional value and high fat, sodium, and acrylamide content (Basaran and Sadighara, 2024). Developing nutritious alternatives, such as malunggay–cassava chips, may help combat the dual burden of malnutrition while supporting local farmers and contributing to food security (Cristuta *et al*., 2019).

Sensory analysis is essential in evaluating consumer acceptability of such products, focusing on appearance, aroma, taste, texture, and overall acceptability (Stone *et al*., 2020). Theories such as Expectation-Confirmation, Sensory-Specific Satiety, and Planned Behavior provide insights into consumer behavior, while recent studies affirm the integration of sensory analysis with behavioral theories in food innovation (Khanna, 2022; Abeywickrema *et al*., 2022; Lambert, 2020; Galler, 2021). Therefore, the present study aimed to develop cassava flour Cebu chips incorporated with varying concentrations of fresh malunggay leaves and to evaluate their sensory acceptability in terms of color, aroma, taste, texture, and overall acceptability.

MATERIALS AND METHODS

Study area

The study was conducted at a public state university in Cebu's fifth district. Spanning 92,000 square meters, the campus serves over 6,145 students as of January 2025, offering undergraduate and graduate programs in engineering, education, hospitality, and technology. The study's respondents included 30% experts, comprising faculty members and industry professionals, and 70% consumers, mainly students from programs such as Technical Vocational Teacher Education and Hotel Management. The university focuses on applied sciences, technology, and community engagement, fostering strong collaborations with local industries and government agencies. Cebu Technological University (CTU) Danao Campus is committed to equipping its graduates for careers in food, hospitality, and technical fields while emphasizing sustainable and health-conscious practices.

Research design

This research employed a combined descriptive and experimental design to evaluate the development and acceptability of cassava flour chips infused with fresh blended malunggay leaves. According to Bahay *et al*. (2025), iterative formulation trials are effective for achieving sensory qualities comparable to conventional products, while Surono (2024) emphasizes the importance of adhering to proper hygiene and sanitation practices during food preparation to prevent cross-contamination. Subsequently, the descriptive phase utilized the Hedonic scale to evaluate consumer acceptability (Wichchukit and O'Mahony , 2022). Respondents completed a structured questionnaire (Supplementary Information-Appendix I: S1) following a sensory test, enabling quantitative assessment of preference and overall product acceptability. This approach allowed for both controlled manipulation of product variables and detailed observational data on consumer response, providing comprehensive insights into product development and market potential.

Standard recipe and procedure

For the chip mixture, *1/4 cup* of blended malunggay

leaves, *10 grams* of ginger, *1/4 cup* water, and 1 teaspoon of salt were prepared. To begin, malunggay leaves were carefully removed from their branches, selecting only the freshest leaves to ensure optimal flavor and nutritional value. The leaves were rinsed under cool water to remove any dirt or impurities and allowed to dry completely. In a blender, *1 cup* of malunggay leaves was combined with *1/4 cup* of water, *5 grams* of ginger, and a pinch of salt, then blended for 2 to 3 minutes until smooth. A *1/4 cup* portion of this blended mixture was measured and transferred to a separate mixing bowl, where *1 cup* of cassava flour was added to create the base for the chips. The mixture was stirred until fully combined. To form individual chips, *1 teaspoon* of the mixture was poured into greased cupcake molds and steamed for approximately 10 minutes. After steaming, the chips were carefully removed from both the steamer and the molds, then arranged on a drying rack, ensuring they did not touch each other to prevent sticking. The chips were then placed in an electric dehydrator and dried for at least 2 hours, or until they were completely moisture-free. In a separate step, oil was heated in a frying pan over low heat for 3 minutes, and the dried chip mixtures were fried for about 5 seconds on each side. Finally, the chips were cooled for 3 to 5 minutes before being transferred into a sealed bag for storage.

Respondents

The respondents were categorized as consumers and experts. A total of 100 participants were included, comprising 70 consumers and 30 experts. The 70 consumer respondents were randomly chosen from the student population, ensuring representation from various courses and year levels through a simple random sampling method in accordance with the principles outlined by Singh and Masuku (2014). In contrast, the 30 expert respondents were individuals who were handling subjects relating to cookery, who were also National Certificate II holders in cookery or allied qualifications, consistent with the guidelines of the Technical Education and Skills Development Authority (TESDA, 2019). The experts were chosen using purposive sampling, a method widely used in sensory evaluation to ensure respondents possess relevant expertise (Anetoh, 2020). This combined approach ensured a representative and qualified sample drawn solely from the Cebu Technological University's Danao Campus community. The number of respondents (100) aligns with recommended panel sizes for consumer and expert testing in sensory evaluation studies (Sipos *et al*., 2021)

Data gathering procedure

Prior to the conduct of the study, a letter requesting approval to proceed was sent to the appropriate office. Once approval was granted (Approval No. 2025-045, dated April 1, 2025) the research team began preparing the three chip formulations in the production area located on the campus premises. The team conducted four rounds of trial and error to perfect the best possible formulation of chips using cassava flour infused with fresh, blended malunggay leaves before proceeding with the actual data-gathering procedure. After finalizing the formulations, the consumers' respondents were identified and individually approached to confirm their availability for the taste test. During the study, each respondent was provided with samples of the different chip formulations and asked to complete a questionnaire to assess their sensory analysis of each variant. The research methodology was thoroughly explained, and the questionnaires were distributed and later collected from the respondents. Throughout the process, it was ensured that all human ethical and health protocols were strictly observed. Finally, the responses to the questionnaires were collated and organized into tables using Excel for further analysis and interpretation. This systematic approach ensured the reliability and validity of the study's findings.

Data analysis

The data were tabulated in Microsoft Excel to ensure that the data were well organized and for easy treatment. Data treatment was done using descriptive and inferential statistics for a correct and reliable result. To analyze and interpret the data on descriptive tests, the researchers computed the weighted mean of the responses and categorized them according to the range of criteria. The sensory analysis of the malunggay and cassava chips in terms of aroma, color, taste, and texture, and the data on the sensory acceptability test using the 5-point hedonic scale were analyzed using a weighted mean. Analysis of Variance (ANOVA) was used to test any significant difference between the levels of acceptability of the respondents on the three malunggay and cassava chips formulations based on the sensory test. SPSS was used for ANOVA for the correct computation and appropriate interpretation of results.

The sensory evaluation of chips using cassava flour infused with fresh blended malunggay leaves employed descriptive statistics (weighted mean) and inferential statistics (one-way ANOVA) using SPSS version 22.0. Sensory attributes (aroma, color, taste, texture) were assessed via a 5-point hedonic scale, with weighted means categorizing results into: *very high to very low* between chip formulations, with sensory scores as dependent variables and formulation type (e.g., 25%, 50%, 100% malunggay) as the independent variable (Terana, 2023). Post-hoc Tukey HSD tests identified specific group differences, while Shapiro-Wilk and Levene's tests confirmed normality and homogeneity of variance (Mat Roni, 2021).

RESULTS AND DISCUSSION

Formulations of Cassava (*Manihot esculenta*) - Malunggay (*Moringa oleifera*) chips

The formulations of cassava flour infused with fresh blended malunggay chips used in this study is detailed in Table 1. Three different blends were prepared by varying the amount of blended Malunggay leaves combined with a constant quantity of commercial cassava flour. Formulation 1 (F_1) consisted of ¼ cup of blended malunggay leaves mixed with 1 cup of cassava flour. Formulation 2 (F_2) increased the malunggay content to ½ cup, maintaining the same amount of cassava flour. The third formulation (F_3) contained the highest proportion of malunggay leaves, using 1 full cup blended with 1 cup of cassava flour. These variations allowed for the assessment of how different malunggay concentrations affect the chips' sensory attributes and overall acceptability, providing insight into the optimal balance between nutritional enhancement and product quality.

Sensory analysis of cassava - malunggay chips formulations

This study emphasizes the significance of integrating consumer preferences and health-related considerations in the development of innovative snack products, specifically cassava and malunggay chips. By offering varied formulations enriched with nutritious ingredients such as Moringa oleifera and cassava, the research aims to produce snacks that promote health while appealing to the senses. The three chip formulations were subjected to sensory evaluation focusing on taste, texture, aroma, color, appearance, and overall acceptability. The results from this analysis provide meaningful insights into consumer preferences and serve as a foundation for enhancing the nutritional quality of snack foods without compromising palatability. Ultimately, the findings support the development of functional snack alternatives that align with modern dietary trends and the growing demand for healthier food options.

Sensory analysis of the first chip formulation

Table 2 presents the sensory evaluation results of the cassava flour infused with ¼ cup of fresh blended malunggay leaves (F_1), as assessed by experts and consumers. The aroma attribute received ($\bar{x}$= 3.96, sd = 0.65) from experts and ($\bar{x}$=3.67, sd = 0.95) from consumers, both classified as Very Good (VG). Regarding color, experts rated it with ($\bar{x}$= 4.46, sd = 0.66), described as Excellent (E), while consumers provided ($\bar{x}$= 4.18, sd = 0.89), indicating the product's color was perceived as appealing. For taste, both groups reported Very Good (VG) ratings: experts scored ($\bar{x}$= 3.83, sd = 0.73) and consumers ($\bar{x}$= 3.64, sd = 0.97). Texture evaluations yielded ($\bar{x}$= 4.5, sd = 0.71) from experts described as Excellent (E) and ($\bar{x}$= 4.14, sd = 0.84) from consumers, interpreted as Very Good (VG). The combined mean scores across both groups were as follows: aroma ($\bar{x}$=3.82, sd = 0.8) interpreted as Very Good (VG), color ($\bar{x}$= 4.32, sd = 0.78) described as appealing by participants, taste ($\bar{x}$= 3.74, sd = 0.85) with a verbal description of Very Good (VG), and texture ($\bar{x}$= 4.32, sd = 0.78) which has an interpretation of Very Good (VG). This outcome agrees with the findings of Rodchom *et al*. (2023), who reported that increasing the proportion of cassava starch in cracker formulations positively influenced crispiness and, to some extent, texture. Specifically, their study showed that higher cassava starch content corresponded with higher crispiness scores during sensory evaluations. Similarly, the results align with Sipos *et al*. (2021), who emphasized the role of trained sensory panels in ensuring reliable evaluations and highlighted texture as one of the most important attributes influencing food acceptance.

Sensory analysis of the second Cebu chip formulation

Table 3 presents the sensory analysis of F_2, cassava flour infused with ½ cup of fresh blended malunggay leaves. The aroma ($\bar{x}$= 3.8, sd=0.90) with a verbal description of Very Good (VG) for the expert and consumer ($\bar{x}$=3.7, sd=0.99) with an interpretation of Very Good (VG). The study by Asmoro *et al*. (2021) highlights the nutritional benefits of combining malunggay leaves with modified cassava flour (MOCAF) in bakery and snack products, where the incorporation of moringa enhances the mineral and fat content. Moringa's rich nutrients—including protein, vitamins, and minerals—compensate for the deficiencies in cassava flour, which is typically low in these components. This blend not only boosts the nutritional profile but also provides added health benefits, such as improved antioxidant and anti-

Table 1. Formulations of Cebu chips using cassava flour infused with fresh-blended malunggay leaves

Materials	Formulation of chips using cassava flour infused with fresh-blended malunggay leaves recipe		
	F_1	F_2	F_3
Malunggay Leaves (blended)	¼ cup	½ cup	1 cup
Ginger (blended)	10g	10g	10g
Salt	1 tsp	1 tsp	1 tsp
Water	¼ cup	¼ cup	¼ cup
Cassava	1 cup	1 cup	1 cup

Table 2. Sensory analysis of F_1

Attributes	Experts		Consumers		Average	
	Mean±SD	VD	Mean±SD	VD	Mean±SD	VD
Aroma	3.96±0.65	VG	3.67±0.95	VG	3.82±0.8	VG
Color	4.46±0.66	E	4.18±0.89	VG	4.32±0.78	E
Taste	3.83±0.73	VG	3.64±0.97	VG	3.74±0.85	VG
Texture	4.5±0.71	E	4.14±0.84	VG	4.32±0.78	E

Legend: 1-1.80-Very Poor (VP), 1.81-2.60-Poor (P), 2.61-3.40-Good (G), 3.41-4.20-Very Good (VG), 4.21-5.0 Excellent (E)

Table 3. Sensory analysis of F_2

Attributes	Experts		Consumers		Average	
	Mean±SD	VD	Mean±SD	VD	Mean±SD	VD
Aroma	3.8±0.90	VG	3.7±0.99	VG	3.75±0.95	VG
Color	3.73±0.96	VG	3.87±1.02	VG	3.8±0.99	E
Taste	3.9±0.97	VG	3.72±1.02	VG	3.81±1.00	VG
Texture	4.2±0.74	E	4.14±0.84	VG	4.17±0.79	E

Legend: 1-1.80-Very Poor (VP), 1.81-2.60-Poor (P), 2.61-3.40-Good (G), 3.41-4.20-Very Good (VG), 4.21-5.0 Excellent (E)

inflammatory properties. For the second attribute, color, experts ($\bar{x}$ = 3.73, sd = 0.96) and consumers ($\bar{x}$ = 3.87, sd = 1.02) both rated the product Very Good (VG). This result differs from F1, which was rated Excellent (E) for color, and is consistent with the observations of Paaki *et al*. (2023), who emphasized that the use of green coloration is positively perceived in traditional contexts (e.g., leafy vegetables and salads) but may be less appealing in less conventional products such as green-colored chips. According to Steiner and Florack (2023), while green can enhance the appeal of foods traditionally associated with this colour (such as salads), its use in atypical contexts (in this case, green-coloured chips) may lead to negative consumer perceptions. Therefore, food producers and marketers should consider cultural norms and consumer expectations when incorporating green hues into food products. For the third attribute, taste, experts' ($\bar{x}$= 3.9, sd=0.97) and consumers' ($\bar{x}$= 3.72, sd=1.02) responses were Very Good (VG). On the product's texture, it is evident that the experts' ($\bar{x}$= 4.2, sd= 0.74) with verbal description of Excellent (E) and consumers' ($\bar{x}$= 4.14, sd= 0.84) with verbal description of Very Good (VG). The combined mean scores across both groups were as follows: aroma averaged ($\bar{x}$=3.75, sd = 0.95) with a verbal description of Very Good (VG), color ($\bar{x}$=3.8, sd = 0.99) described as appealing by participants, taste ($\bar{x}$=3.81, sd = 1.00) with a verbal description of Very Good (VG), and texture ($\bar{x}$=4.17, sd = 0.79) with a verbal description of Very Good (VG). The findings indicate that the sensory analysis of the combination of cassava flour and blended malunggay leaves is well-received by both experts and consumers, with positive ratings across all attributes, particularly in texture and taste.

Sensory analysis of the third Cebu chip formulation

Table 4 presents the sensory analysis of F_3, which consists of cassava flour infused with 1 cup of fresh blended malunggay leaves. The aroma received a mean score of ($\bar{x}$= 3.86, sd = 0.88) from experts, with a verbal description of Very Good (VG), and ($\bar{x}$= 3.41, sd = 1.14) from consumers, also interpreted as Very Good (VG). For the second attribute, color, experts ($\bar{x}$ = 3.66, sd = 0.90) and consumers ($\bar{x}$ = 3.61, sd = 1.32) agreed that the formulation had an appealing appearance. Regarding taste, experts' evaluations ($\bar{x}$ = 3.73, sd = 0.85) were described as Very Good (VG), while consumers' scores ($\bar{x}$ = 3.15, sd = 1.12) corresponded to a Good (G) rating. For the product's texture, experts ($\bar{x}$ = 4.13, sd = 0.80) rated it as Very Good (VG), while consumers ($\bar{x}$ = 3.9, sd = 0.91) also provided a Very Good (VG) rating. The combined mean scores across both groups were as follows: aroma averaged ($\bar{x}$ = 3.63, sd = 1.01) Very Good (VG), color averaged ($\bar{x}$ = 3.64, sd = 1.11) described as appealing by participants, taste averaged ($\bar{x}$ = 3.44, sd = 0.99) Very Good (VG), and texture averaged ($\bar{x}$ = 4.02, sd = 0.86) Very Good (VG). These favorable sensory ratings support the findings of Klopčič *et al*. (2020), who emphasized that consumers place high importance on product attributes that contribute to health and sensory appeal. In their study, on dairy and functional food preparations, nutrition and health claims were valued more than visual packaging elements, suggesting that the perceived health benefits of ingredients like malunggay may positively influence acceptance. They also found that younger consumers were more responsive to visual and sensory cues, which may explain the favorable responses across all attributes, particularly for aroma and texture. Trust and

Table 4. Sensory analysis of F_3

Attributes	Experts		Consumers		Average	
	Mean±SD	VD	Mean±SD	VD	Mean±SD	VD
Aroma	3.86±0.88	VG	3.41±1.14	VG	3.63±1.01	VG
Color	3.66±0.90	VG	3.61±1.32	VG	3.64±1.11	VG
Taste	3.73±0.85	VG	3.15±1.12	G	3.44±0.99	VG
Texture	4.13±0.80	VG	3.9±0.91	VG	4.02±0.86	VG

Legend: 1-1.80-Very Poor (VP), 1.81-2.60-Poor (P), 2.61-3.40-Good (G), 3.41-4.20-Very Good (VG), 4.21-5.0 Excellent (E)

Table 5. Analysis of variance on significant differences in respondents' perception of the different attributes of chips using cassava flour infused with fresh blended malunggay leaves

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	95.49	14	6.82071	7.17913	0.000	1.70012
Within Groups	1125.84	1185	0.95008			
Total	1221.33	1199				

familiarity with natural health-promoting ingredients can enhance consumer acceptance, as reflected in the consistently high ratings for the formulation's sensory qualities. However, the results of the present study revealed that the higher amount of malunggay in F_3 may have hindered the texture of the chips. This was reflected in the sensory evaluation, where F_3 received only a Very Good (VG) rating for texture, compared to F1, which achieved an Excellent (E) rating. This observation aligns with the findings of Rodchom *et al*. (2023), which state that the addition of other ingredients to cassava starch may negatively affect certain attributes. Their study suggests that "fish protein" — and in the present case, the high content of blended malunggay in the cassava–malunggay chips, particularly Formulation 3 (F3), which is rich in protein and fiber — may hinder expansion through its interaction with starch granules, thereby reducing the crispiness of the chips compared to F_1.

Analysis of variance on significant mean differences in respondents' perception

The Analysis of Variance (ANOVA) was used to statistically analyze the data, revealing a significant difference in the level of acceptability among the cassava flour infused with fresh blended malunggay chips formulations. As shown in Table 5, the analysis considered 15 comparison groups (Between Groups, df = 14), which represent the different combinations of respondents' (experts and consumers) sensory evaluations across the attributes of aroma, color, taste, and texture. The Within Groups variation (df = 1185) accounts for individual differences in ratings within each group.

The results show that the F-value (7.17913) exceeds the F critical value (1.70012), and the P-value (0.000) is far below 0.05, leading to the rejection of the null hypothesis (H□). Therefore, there is a statistically significant difference in the sensory evaluation of chips made with cassava flour infused with fresh-blended malunggay leaves between expert and consumer respondents across the sensory attributes of aroma, colour, taste, and texture.

Conclusion

Based on the data analysis and interpretation, the sensory evaluation of Cebu chips using cassava flour infused with fresh, blended malunggay leaves indicated that the products were acceptable in terms of aroma, colour, taste, and texture. The study revealed a significant difference in acceptability ratings between expert and consumer respondents across these sensory attributes. While both experts and consumer groups found Cebu chips made with cassava flour infused with fresh, blended malunggay leaves acceptable, slight variations in sensory ratings were noted, with formulation F1 emerging as the most preferred option. The ANOVA results further highlight distinct preferences and sensitivities in evaluating the chips, underscoring the importance of expertise in sensory assessments. These findings align with recent research that emphasizes the role of sensory evaluation in food product development and consumer acceptance.

Supplementary Information

The author(s) is responsible for the content or functionality of any supplementary information. Any queries regarding the same should be directed to the corresponding author. The supplementary information is available for download from the article's webpage and will not be included in the print copy.

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Conflict of interest

The authors declare that there is no competing interest.

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