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From Waste to Taste: Banana Peel Powder in Cookie Formulation, Sensory Acceptability, and Technology Guide

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ABSTRACT

This study developed and evaluated banana chocolate chip cookies incorporating varying amounts of banana peel powder and formulated a Technology Guide for sustainable food preparation. Anchored in Circular Economy Theory, Food Product Development Theory, and Sensory Acceptability Theory, the study employed a quantitative experimental design involving three formulations containing 20 g, 40 g, and 60 g of banana peel powder. Conducted at Bugho Integrated School, San Fernando, Cebu, during the school year 2025–2026, the study involved 50 purposively selected respondents comprising 10 teacher-expert panelists and 40 student-consumer panelists. Sensory acceptability was assessed in terms of color, aroma, texture, and flavor using a structured questionnaire with a 9-point Hedonic Scale. Descriptive statistics and one-way Analysis of Variance (ANOVA) were employed at the 0.05 significance level. Results revealed favorable sensory acceptability across all formulations. Treatment 2 (40 g) obtained the highest overall expert rating (8.15), while Treatment 3 (60 g) received the highest consumer rating (7.61). However, no statistically significant differences were observed among treatments for either expert ($p = 0.287842$) or consumer evaluations ($p = 0.596209$). Treatment 2 was recommended for the Technology Guide based on favorable expert ratings and practical suitability. The study was limited to sensory evaluation and did not establish nutritional composition, shelf life, or laboratory-validated food safety. Further investigation of these characteristics and broader consumer acceptability was recommended. The study aligns with Sustainable Development Goal (SDG) 12, Responsible Consumption and Production, and SDG 4, Quality Education, through agricultural waste utilization and practical food-processing instruction. Its sustainability contribution lies in demonstrating potential banana peel waste reduction, resource efficiency, educational application, and opportunities for community-based food innovation.

Keywords: *Agricultural Waste Utilization, Banana Chocolate Chip Cookies, Banana Peel Powder, Circular Economy, Food Product Development, Sensory Acceptability, Sustainable Food Preparation, Technology Guide*

1. INTRODUCTION

Food waste is a growing environmental and socio-economic concern, particularly in agricultural communities where potentially valuable by-products are frequently discarded. Banana peels, commonly treated as household and food-processing waste, represent an underutilized resource with potential applications in food production (United Nations Environment Programme, 2024; Bishnoi et al., 2023). Studies have identified dietary fiber, pectin, and bioactive compounds in banana peels, indicating their potential as ingredients in value-added food products. Happi Emaga et al. (2007) reported substantial dietary fiber and pectin content in banana and plantain peels, while Zou et al. (2022) emphasized their nutritional and functional potential in food applications. Incorporating banana peel powder into bakery products offers an opportunity to promote resource efficiency and sustainable food innovation. However, its incorporation may influence product characteristics, particularly color, aroma, texture, and flavor, making sensory evaluation essential in determining acceptable formulations (Pomasa et al., 2025). In the Philippines, where bananas are widely produced and consumed, the utilization of banana peels supports circular food-system practices that transform agricultural by-products into useful resources (Ellen MacArthur Foundation, 2019). According to the Philippine Statistics Authority (2025), banana production in Cebu reached 56,613.22 metric tons during the second semester of 2024, representing 82.27% of the province's major fruit crop production. Despite the potential of banana peel powder, its practical application in household food preparation, Home Economics education, and small-scale food production requires accessible and standardized procedures. Accordingly, this study examined the formulation and sensory acceptability of banana chocolate chip cookies incorporating varying amounts of banana peel powder and developed a Technology Guide to support sustainable food preparation and resource utilization.

Research Problem

Recent research documents opportunities to use banana peel as a functional ingredient in bakery products, while emphasizing the need to balance formulation level, texture, and consumer liking (Ismail et al., 2024; Pomasa et al., 2025; Karaman et al., 2025). Studies on banana-peel pectin and bioactive ingredients also support the rationale for examining peel-derived food ingredients, without establishing the nutrient composition of the cookies tested here (Ahsan et al., 2024; Khamsaw et al., 2024; Akhter et al., 2024). The increasing disposal of banana peels contributes to agricultural waste accumulation despite their potential nutritional and economic value. Although existing research has demonstrated their suitability for value-added applications, incorporating banana peel powder into food products requires careful consideration of sensory quality and consumer acceptance. Different incorporation levels may affect the physical and sensory characteristics of cookies, emphasizing the need for systematic formulation and evaluation (Pomasa et al., 2025). Furthermore, a gap exists between research on banana peel utilization and the availability of practical procedures suitable for educational institutions, households, and small-scale food producers. Developing accessible food-processing guidelines supports the productive use of agricultural by-products and aligns with circular-economy principles (Ellen MacArthur Foundation, 2019). To address these concerns, the study investigated the sensory acceptability of banana chocolate chip cookies containing 20 g, 40 g, and 60 g of banana peel powder at Bugho Integrated School, San Fernando, Cebu, during the school year 2025–2026. Specifically, it examined the acceptability of the formulations in terms of color, aroma, texture, and flavor; determined whether significant differences existed among the treatments; and established a basis for developing a Technology Guide for standardized cookie production.

Assumptions of the Study

The study was guided by the assumption that banana peel powder could be incorporated into banana chocolate chip cookies as an alternative food ingredient while maintaining acceptable sensory characteristics. This assumption was supported by previous findings regarding the dietary fiber, pectin, and bioactive components of banana peels (Wang et al., 2026; Wani & Dhanya, 2025). It was further assumed that varying the amount of banana peel powder could influence the sensory acceptability of cookies, particularly their color, aroma, texture, and flavor. Standardized preparation procedures and consistent quantities of other ingredients were maintained to facilitate comparison among the formulations. The study also assumed that evaluations obtained from expert and consumer panelists using a 9-point Hedonic Scale could provide a basis for assessing product acceptability. The null hypothesis stated that there was no significant mean difference in the acceptability of the three formulations at the 0.05 level of significance. Finally, the study assumed that sensory evaluation findings could guide the selection of a suitable formulation and the development of a practical Technology Guide for Home Economics instruction, household food preparation, and small-scale food production.

Objectives of the Study

The general objective of this study was to develop and evaluate banana chocolate chip cookies incorporating banana peel powder and use the findings as a basis for preparing a Technology Guide. Specifically, the study aimed to formulate cookies containing three levels of banana peel powder incorporation: 20 g (Treatment 1), 40 g (Treatment 2), and 60 g (Treatment 3); determine their sensory acceptability in terms of color, aroma, texture, and flavor using a 9-point Hedonic Scale; establish whether significant differences existed in acceptability among the formulations at the 0.05 significance level; and develop a Technology Guide outlining standardized procedures for banana peel powder preparation and cookie production. Through these objectives, the study sought to demonstrate the potential of banana peel powder as a value-added food ingredient while providing practical knowledge applicable to sustainable food production and Home Economics education.

Conceptual and Theoretical Framework

The study was anchored in Circular Economy Theory, Food Product Development Theory, and sensory acceptability principles, which collectively provide a foundation for transforming agricultural by-products into value-added food products through systematic formulation, sensory evaluation, and sustainable resource utilization. Recent studies have emphasized the potential of banana peels as sources of functional compounds that may be recovered and incorporated into food products, supporting circular food systems and sustainable food innovation (Bishnoi et al., 2023; Kezer et al., 2025; Wani & Dhanya, 2025). Circular Economy Theory, as discussed by the Ellen MacArthur Foundation (2019), emphasizes waste prevention, resource efficiency, and the continuous utilization of materials within productive systems. This framework supports the transformation of discarded banana peels into banana peel powder as an alternative ingredient in cookie production. Recent research on banana peel valorization further supports the potential of converting agricultural by-products into value-added food ingredients (Bishnoi et al., 2023; Kezer et al., 2025). In the present study, circular economy principles guided the utilization of banana peel powder in three cookie formulations containing 20 g, 40 g, and 60 g, demonstrating a potential approach to reducing food-processing waste and promoting sustainable food preparation. Food Product Development Theory, particularly Cooper's (2015) Stage-Gate Model, provides a systematic approach to developing and evaluating new products through sequential stages of formulation, testing, assessment, and decision-making. This model served as a conceptual guide for the development of banana chocolate chip

cookies incorporating varying amounts of banana peel powder. The product development process involved ingredient preparation, standardized formulation, cookie production, sensory evaluation, and the selection of a suitable formulation for the proposed Technology Guide. Recent literature on banana peel utilization in food applications further supports the importance of evaluating alternative ingredients for their technological and sensory suitability (Wani & Dhanya, 2025). Although the study did not implement the complete commercial Stage-Gate process, its formulation and evaluation activities reflected selected principles of systematic product development. Sensory acceptability principles, grounded in the established sensory evaluation methods of Meilgaard et al. (2006), explain how consumer preferences can be assessed through sensory attributes such as color, aroma, texture, and flavor. These principles provided the methodological foundation for evaluating the three banana peel powder cookie formulations using a 9-point Hedonic Scale. The scale enabled teacher-expert and student-consumer panelists to express their degree of liking for each formulation. Sensory evaluation was essential in determining whether the incorporation of banana peel powder resulted in products considered acceptable by the respondents. The resulting evaluations served as the basis for comparing the formulations and identifying a suitable treatment for inclusion in the Technology Guide. The study was further supported by Philippine laws and government policies related to environmental sustainability, food safety, and responsible resource utilization. Republic Act No. 9003, also known as the Ecological Solid Waste Management Act of 2000, promotes waste minimization, recycling, resource conservation, and recovery through environmentally sustainable solid waste management practices (Republic Act No. 9003, 2001). Republic Act No. 10611, or the Food Safety Act of 2013, establishes requirements for maintaining food safety throughout the food supply chain. Additionally, Department of Health Administrative Order No. 153, series of 2004, provides guidelines on current good manufacturing practices, including sanitation, food handling, and processing procedures. These legal and regulatory provisions provide relevant guidance for the preparation and handling of banana peel powder and cookies. However, compliance with general food-handling practices does not establish that the developed formulations have undergone laboratory-based food safety validation. The study also recognizes the relevance of food innovation, technology transfer, and skills development in promoting sustainable food production. The conversion of banana peels into an alternative bakery ingredient offers opportunities for practical applications in Home Economics and Technology and Livelihood Education. Through the development of a Technology Guide, the research aims to translate the findings of sensory evaluation into accessible procedures that may support instructional activities, household food preparation, and small-scale food product development. This application is consistent with broader objectives of sustainable resource utilization, agricultural by-product valorization, and food waste reduction. Collectively, these theoretical, methodological, and regulatory foundations guided the conceptual process of the study using an Input–Process–Output (IPO) framework. The input consisted of banana peel powder, other cookie ingredients, preparation materials, and three formulations containing 20 g, 40 g, and 60 g of banana peel powder. The process involved banana peel powder preparation, standardized cookie production, sensory evaluation by teacher-expert and student-consumer panelists, and statistical analysis using descriptive statistics and one-way Analysis of Variance (ANOVA). The output consisted of the evaluated cookie formulations and a Technology Guide based on the selected formulation. Through this framework, the study establishes a connection among agricultural waste utilization, systematic food product development, sensory acceptability, and sustainable food preparation techniques.

Sustainable Development Goal and Multidisciplinary Sustainability Relevance

The study aligns with selected United Nations Sustainable Development Goals by promoting agricultural waste utilization, sustainable food innovation, practical education, and

opportunities for community-based food production. SDG 12 – Responsible Consumption and Production is the primary alignment of the study. Converting discarded banana peels into a functional food ingredient supports waste reduction, resource efficiency, and the productive reuse of agricultural by-products. This approach reflects circular-economy principles that encourage the transformation of waste into valuable resources (Ellen MacArthur Foundation, 2019). SDG 4 – Quality Education is supported through the development of a Technology Guide that may serve as an instructional resource in Home Economics and Technology and Livelihood Education. The guide provides practical procedures for food preparation, product formulation, and sustainable resource utilization, connecting classroom learning with food-processing applications. SDG 9 – Industry, Innovation and Infrastructure is reflected in the development and evaluation of banana peel powder cookies as an innovative food product. The study applies food-processing techniques and sensory evaluation to explore the utilization of an agricultural by-product, consistent with initiatives supporting food technology and value-added product development (Bishnoi et al., 2023). SDG 8 – Decent Work and Economic Growth is relevant to the potential application of the developed formulation and Technology Guide in small-scale food enterprises. Utilizing locally available banana peels may provide opportunities for product diversification, entrepreneurship, and community-based economic activities. The study also relates to environmental, educational, technological, and socio-economic sustainability. Environmentally, it promotes the productive utilization of banana peels that would otherwise be discarded. Educationally, it provides practical knowledge for integrating sustainable food preparation into Home Economics instruction. Technologically, it demonstrates the application of standardized food-processing procedures and sensory evaluation in developing a value-added product. Socio-economically, it offers a potential basis for household food innovation and small-scale enterprise development. Overall, the study contributes to sustainable food production by exploring the conversion of banana peel waste into an acceptable cookie product and translating the research findings into a practical Technology Guide. Its contribution emphasizes resource efficiency, food innovation, skills development, and the potential for sustainable community-based food production.

2. METHODOLOGY

Research Design

The study utilized a quantitative research design involving the formulation and sensory evaluation of banana chocolate chip cookies with varying levels of banana peel powder incorporation. Three experimental treatments were developed: Treatment 1 (T1) contained 20 g of banana peel powder, Treatment 2 (T2) contained 40 g, and Treatment 3 (T3) contained 60 g. All treatments followed the same basic cookie recipe, with the amount of banana peel powder serving as the independent variable. Other ingredients, preparation procedures, baking conditions, and equipment were kept constant to facilitate comparison of sensory characteristics. The study followed an Input–Process–Output (IPO) model. Inputs consisted of the ingredients, materials, equipment, and three cookie formulations. The process involved banana peel powder preparation, cookie formulation, baking, sensory evaluation, data collection, and statistical analysis. The outputs were the evaluated cookie formulations and a Technology Guide containing standardized preparation procedures.

Research Locale or Study Setting

The study was conducted at Bugho Integrated School in San Fernando, Cebu, Philippines. The school offers basic education programs, including Technology and Livelihood Education (TLE), particularly Home Economics, which provides students with foundational knowledge and skills in food preparation. The institution was selected because of its facilities suitable for food preparation and its population of students with basic food-related knowledge. The school had

approximately 250 students and 20 teachers, providing an appropriate setting for product preparation and sensory evaluation. Selected Grade 9 and Grade 10 students participated as consumer evaluators, while professional teachers served as expert panelists.

Participants or Data Sources

The study involved 50 respondents comprising 40 student-consumer panelists and 10 professional teacher-expert panelists. The consumer group consisted of 20 Grade 9 students and 20 Grade 10 students from Bugho Integrated School, selected through purposive sampling based on their foundational knowledge and skills in food preparation. The student panelists represented 80% of the respondents, while the expert panelists accounted for 20%. Both groups evaluated the three cookie formulations according to color, aroma, texture, and flavor. The professional teachers provided expert assessments, while the students contributed consumer evaluations of product acceptability.

Research Instruments or Materials

The primary research instrument was a structured sensory evaluation questionnaire using a 9-point Hedonic Scale to determine the acceptability of the three banana peel powder cookie formulations. Respondents assessed color, aroma, texture, and flavor, with higher ratings indicating greater sensory acceptability. Panelists received an orientation regarding the interpretation and use of the rating scale before evaluating the samples. The ingredients used in cookie production included all-purpose flour, banana peel powder, baking soda, softened butter, brown sugar, salt, egg, mashed ripe banana, vanilla extract, and chocolate chips. Each formulation contained 1 cup of all-purpose flour, ½ teaspoon of baking soda, ¼ cup of softened butter, ½ cup of brown sugar, ½ teaspoon of salt, 1 egg, ½ mashed ripe banana, 1 teaspoon of vanilla extract, and ½ cup of chocolate chips. The formulations differed only in the incorporation of 20 g, 40 g, or 60 g of banana peel powder. The materials and equipment included mixing bowls, measuring cups and spoons, a weighing scale, spatula, baking trays, an oven, a blender or grinder, a sieve, and packaging materials. These were used for preparing banana peel powder, mixing ingredients, baking cookies, and handling the finished products.

Data Gathering Procedure

Data gathering was conducted through preliminary preparation, product development, sensory evaluation, and post-evaluation activities. Before the experiment, permission was secured from the school authorities, the required materials and ingredients were prepared, and respondents were oriented regarding the study's purpose and sensory evaluation procedures. Banana peel powder was prepared by thoroughly washing the banana peels, removing their stems and tips, and boiling them for approximately 10 minutes to reduce bitterness. The peels were sliced into thin pieces and oven-dried at approximately 90–100°C until completely dry. The dried peels were ground into powder, sieved to obtain a uniform particle size, and stored in airtight containers before incorporation into the cookie formulations. The cookies were prepared using standardized procedures across all treatments. The oven was preheated to 180°C, while the dry ingredients, consisting of all-purpose flour, banana peel powder, baking soda, and salt, were combined. In a separate bowl, softened butter and brown sugar were creamed before adding the egg, mashed banana, and vanilla extract. The dry ingredients were gradually incorporated into the wet mixture, followed by the chocolate chips. The dough was portioned onto baking trays and baked for approximately 10–12 minutes until the edges were lightly golden brown. The cookies were cooled before serving or packaging. The three formulations were presented as coded samples to the expert and consumer panelists to minimize evaluation bias. Each respondent independently assessed the samples using the 9-point Hedonic Scale according to color, aroma, texture, and flavor. Completed evaluation questionnaires were collected, organized, and

prepared for statistical analysis. The resulting data served as the basis for determining sensory acceptability and developing the Technology Guide.

Data Analysis

The sensory evaluation data were analyzed using descriptive statistics and Analysis of Variance (ANOVA). Mean scores were computed to determine the acceptability of each formulation according to color, aroma, texture, and flavor. Higher mean ratings indicated greater sensory acceptability, while lower ratings reflected reduced preference for the evaluated attributes. The mean scores obtained from the expert and consumer panels were compared to identify differences in the acceptability of the three formulations. One-Way ANOVA was employed at the 0.05 level of significance to determine whether statistically significant mean differences existed among the treatments. The null hypothesis stated that there was no significant mean difference in the sensory acceptability of the three banana peel powder cookie formulations. The statistical findings were interpreted to establish the acceptability of the treatments and provide a basis for selecting a recommended formulation for the Technology Guide.

Ethical Consideration

The study observed ethical principles concerning informed consent, voluntary participation, confidentiality, food safety, and research integrity. Before the sensory evaluation, respondents were informed about the study's purpose, procedures, ingredients, and intended use of the collected data. Informed consent was obtained from participants, who were advised of their right to withdraw at any stage without penalty. Participant privacy was protected by excluding personal names from the analysis and reporting the results in aggregate form. Completed evaluation forms were securely maintained and designated for destruction after the final thesis defense. Food safety precautions were observed during the preparation, handling, and serving of cookie samples in accordance with the Food Safety Act (RA 10611). Ingredients were disclosed before the tasting activity, including banana peel powder, wheat flour, eggs, butter, and other components that could cause allergic reactions or sensitivities. Respondents were screened for known food allergies, and individuals with identified sensitivities were advised not to participate in the tasting activity. The researcher also adhered to the principle of nonmaleficence by prioritizing participant safety and maintaining the integrity of the collected data. Evaluation results were documented and analyzed without manipulation or fabrication to ensure objective reporting of the sensory acceptability of the developed cookie formulations.

3. RESULTS AND DISCUSSION

3.1 Formulation and Sensory Acceptability of Banana Peel Powder Cookies

3.1.1 Development of Banana Peel Powder Cookie Formulations

Three banana chocolate chip cookie formulations were developed with different levels of banana peel powder incorporation. Treatment 1 (T1) contained 20 g, Treatment 2 (T2) contained 40 g, and Treatment 3 (T3) contained 60 g of banana peel powder. All formulations used the same basic ingredients, including all-purpose flour, baking soda, butter, brown sugar, salt, egg, mashed ripe banana, vanilla extract, and chocolate chips. The amount of banana peel powder was the only ingredient quantity varied among treatments. The resulting cookies were subjected to sensory evaluation by expert and consumer panelists. The development of the three formulations provided a basis for determining the sensory acceptability of banana peel powder as an alternative ingredient in cookie production. Maintaining consistent ingredient proportions and preparation procedures allowed the evaluation to focus on differences associated with the varying amounts of banana peel powder. This approach supported the study's objective of identifying an acceptable formulation for practical food preparation and product development.

3.1.2 Sensory Acceptability in Terms of Color

The expert panel rated Treatment 3 highest in color, with a mean score of 8.40, followed by Treatment 2 at 8.20 and Treatment 1 at 7.30. Treatments 2 and 3 were interpreted as "Like Very Much," while Treatment 1 was interpreted as "Like Moderately." Similarly, the consumer panel rated Treatment 3 highest at 7.83, followed by Treatment 1 at 7.55 and Treatment 2 at 7.48. All consumer ratings were interpreted as "Like Moderately." These findings indicate that Treatment 3, containing 60 g of banana peel powder, was the most preferred formulation in terms of color among both groups of evaluators. Although expert panelists generally assigned higher ratings than consumer panelists, both groups demonstrated similar preferences for Treatment 3. The results suggest that the highest level of banana peel powder incorporation produced the most favorably evaluated color among the three formulations.

3.1.3 Sensory Acceptability in Terms of Aroma

For aroma, the expert panel rated Treatment 2 highest, with a mean score of 8.10, followed by Treatment 3 at 7.50 and Treatment 1 at 7.30. Treatment 2 was interpreted as "Like Very Much," while Treatments 1 and 3 were interpreted as "Like Moderately." The consumer panel similarly rated Treatment 2 highest at 7.53, followed by Treatment 3 at 7.45 and Treatment 1 at 7.40. All consumer ratings were interpreted as "Like Moderately." The results indicate that Treatment 2, containing 40 g of banana peel powder, was the most preferred formulation in terms of aroma among both expert and consumer panelists. The agreement between the two groups suggests that the moderate incorporation level produced the most favorably evaluated aroma. Nevertheless, all three formulations received favorable ratings, indicating acceptable aroma characteristics across the treatments.

3.1.4 Sensory Acceptability in Terms of Texture

The expert panel rated Treatment 2 highest in texture, with a mean score of 8.20, followed by Treatment 3 at 7.60 and Treatment 1 at 7.50. Treatment 2 was interpreted as "Like Very Much," while Treatments 1 and 3 were interpreted as "Like Moderately." In contrast, the consumer panel rated Treatment 3 highest at 7.48, while Treatments 1 and 2 obtained identical mean scores of 7.30. All consumer ratings were interpreted as "Like Moderately." These findings demonstrate differences in texture preferences between the two evaluation groups. Expert panelists favored Treatment 2, containing 40 g of banana peel powder, whereas consumer panelists preferred Treatment 3, containing 60 g. Despite these variations, all formulations received ratings ranging from "Like Moderately" to "Like Very Much," indicating generally favorable texture acceptability.

3.1.5 Sensory Acceptability in Terms of Flavor

For flavor, the expert panel rated Treatment 2 highest, with a mean score of 8.00, followed by Treatment 3 at 7.80 and Treatment 1 at 7.50. Treatment 2 was interpreted as "Like Very Much," while Treatments 1 and 3 were interpreted as "Like Moderately." Conversely, the consumer panel rated Treatment 1 highest at 7.75, followed by Treatment 3 at 7.68 and Treatment 2 at 7.55. All consumer ratings were interpreted as "Like Moderately." The findings indicate that flavor preferences differed between expert and consumer panelists. Experts preferred Treatment 2, containing 40 g of banana peel powder, while consumers favored Treatment 1, containing 20 g. Although the preferred formulations varied, all treatments received favorable flavor ratings,

demonstrating that the three incorporation levels produced cookies with generally acceptable flavor characteristics.

3.2 Significant Differences in Sensory Acceptability Among Treatments

3.2.1 Differences in Acceptability as Evaluated by Expert Panelists

The expert panel obtained overall mean ratings of 7.35 for Treatment 1, 8.15 for Treatment 2, and 7.96 for Treatment 3. Treatment 2 received the highest overall mean rating, followed by Treatment 3 and Treatment 1. One-way ANOVA yielded an F-value of 1.304593 and a p-value of 0.287842, with an F-critical value of 3.354131. Since the p-value exceeded the 0.05 significance level and the computed F-value was lower than the critical value, the null hypothesis was not rejected. These results indicate that the differences in overall acceptability among the three formulations were not statistically significant according to the expert panel. Although Treatment 2 obtained the highest mean rating, its numerical advantage did not establish statistical superiority over the other formulations. Thus, the three treatments were considered comparable in terms of their overall sensory evaluation by expert panelists.

3.2.2 Differences in Acceptability as Evaluated by Consumer Panelists

The consumer panel obtained overall mean ratings of 7.50 for Treatment 1, 7.35 for Treatment 2, and 7.61 for Treatment 3. Treatment 3 received the highest overall rating, followed by Treatment 1 and Treatment 2. The one-way ANOVA produced an F-value of 0.519456 and a p-value of 0.596209, with an F-critical value of 3.073763. Since the p-value was greater than 0.05 and the computed F-value was below the critical value, the null hypothesis was not rejected. The findings indicate that the differences in overall acceptability among the three formulations were not statistically significant according to the consumer panel. Although Treatment 3 obtained the highest mean score, its advantage over the other treatments was not statistically significant. Therefore, the three formulations demonstrated comparable overall sensory acceptability among consumer respondents.

3.3 Comparison of Expert and Consumer Sensory Evaluations

Contemporary consumer studies show that responses to upcycled foods depend on sensory qualities, sustainability information, and product framing (Cela et al., 2024; Melios et al., 2025; Cao, 2025; Nguyen et al., 2025; Tra & Luan, 2026). These findings provide context for interpreting differences between the teacher and student panels, but they do not establish why the present respondents preferred particular treatments. The expert and consumer panels demonstrated varying preferences across the four sensory attributes. Both groups rated Treatment 3 highest in color and Treatment 2 highest in aroma. However, expert panelists preferred Treatment 2 in texture and flavor, while consumer panelists rated Treatment 3 highest in texture and Treatment 1 highest in flavor. In the overall evaluation, Treatment 2 obtained the highest mean rating from the expert panel at 8.15, whereas Treatment 3 received the highest mean rating from the consumer panel at 7.61. These findings indicate that the preferred formulation varied according to the sensory attribute and evaluator group. Although expert and consumer preferences differed in texture, flavor, and overall ratings, all three formulations received favorable evaluations. Furthermore, the absence of statistically significant differences among treatments in both panels indicates that none of the formulations demonstrated statistically superior overall acceptability. The results support the potential use of banana peel powder at the three tested incorporation levels in cookie production.

3.4 Development of the Technology Guide

Recent work on fruit-peel valorization and bakery applications further supports documenting standardized preparation and testing procedures (Nitisuk et al., 2025; Huang et al., 2026; Wang et al., 2026). Related studies on red banana peel cookies, peel-enriched biscuits, and banana peel flour prototypes demonstrate that processing and formulation choices can affect physical and sensory quality (Aravind et al., 2025; Utilization of fruits and vegetables wastes, 2024; Spectroscopic and compositional analysis, 2026). Circular-bioeconomy research additionally identifies opportunities for wider agricultural by-product utilization (Hitlamani et al., 2026). These are external findings and do not constitute laboratory validation of the present cookies. Based on the sensory evaluation findings, Treatment 2, containing 40 g of banana peel powder, was selected as the recommended formulation for the Technology Guide. This treatment obtained the highest overall mean rating from the expert panel at 8.15 and received favorable evaluations for aroma, texture, and flavor. The developed Technology Guide provides standardized procedures for banana peel powder preparation, cookie formulation, mixing, baking, cooling, packaging, storage, and food safety practices. The selection of Treatment 2 was based on its favorable expert evaluation and practical suitability rather than statistically significant superiority over the other treatments. The Technology Guide translates the study's findings into an instructional and practical resource for students, teachers, households, and individuals interested in food product development. Its application demonstrates the potential utilization of banana peel powder as a value-added ingredient while supporting food waste reduction, sustainable food preparation, and innovation in small-scale food production.

4. CONCLUSIONS AND RECOMMENDATIONS

The study concluded that banana peel powder can be successfully incorporated into banana chocolate chip cookies while maintaining favorable sensory acceptability in terms of color, aroma, texture, and flavor. Among the three formulations, Treatment 2 (40 g) obtained the highest overall mean rating from the expert panel (8.15), while Treatment 3 (60 g) received the highest rating from the consumer panel (7.61). However, one-way ANOVA revealed no statistically significant differences among the formulations at the 0.05 level of significance, indicating comparable overall acceptability. Treatment 2 was selected as the recommended formulation based on its favorable expert evaluation and practical suitability rather than statistical superiority. The developed Technology Guide demonstrates the potential of utilizing banana peel powder as a value-added food ingredient while promoting food waste reduction, sustainable food preparation, and food product innovation.

The study recommends Treatment 2, containing 40 g of banana peel powder, as the preferred formulation for the Technology Guide because of its favorable sensory performance and practical suitability. The guide may be utilized by students, teachers, households, and communities as an instructional and practical resource for sustainable food preparation and agricultural waste utilization. Further research is recommended to determine the nutritional composition, shelf life, storage stability, and food safety of banana peel powder cookies; investigate additional incorporation levels and their effects on sensory, physical, and nutritional characteristics; and explore their application in other bakery products. Future studies may also involve larger and more diverse respondent groups and compare banana peel powder obtained from different banana varieties and stages of ripeness to provide broader evidence regarding product acceptability and potential food applications.

The study was limited to the development and sensory evaluation of three banana chocolate chip cookie formulations containing 20 g, 40 g, and 60 g of banana peel powder. The evaluation involved 50 respondents, comprising 10 expert panelists and 40 Grade 9 and Grade 10 student-consumer panelists from Bugho Integrated School in San Fernando, Cebu, during the school year 2025–2026. Sensory acceptability was assessed only in terms of color, aroma, texture, and flavor using a 9-point Hedonic Scale. The study did not include laboratory analysis of nutritional composition, dietary fiber, mineral content, shelf life, storage stability, or formal food safety validation. Furthermore, the investigation was confined to the selected formulations and respondents, without examining other banana varieties, additional incorporation levels, or broader consumer populations. Consequently, the findings primarily reflect the sensory acceptability of the developed formulations within the specified research setting and provide a basis for further investigation.

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