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Assessing the acceptability of spent coffee grounds in Broas: A sustainable innovation

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Abstract

This study determined and assessed the acceptability of spent coffee grounds (SCG) Broas at one of the state universities in Cebu City, Philippines during the academic year 2025–2026 as a basis for a sustainable food product development. To reduce food waste while also preserving product quality, this explored the use of SCG as an additional ingredient in broas. Three SCG formulations were made: T1 (12 grams), T2 (24 grams), and T3 (36 grams). A 9-point Hedonic Scale for sensory attributes and a 5-point Likert scale for feasibility were used by a total of 45 respondents – 25 student and 20 faculty members with food-related backgrounds that assessed the samples. Data were analyzed using frequency count, weighted mean, average weighted mean, and Spearman Rank-Order Correlation. Treatment 1 with 12 grams of SCG received the highest rating in most sensory attributes according to the results. Additionally, respondents agreed that adding SCG to broas is practical, secure, and environmentally friendly. Overall, the study concludes that SCG can be utilized as a sustainable ingredient in broas while still being acceptable to consumer.

Keywords: Spent Coffee Gounds; Broas; Food Service Management; Experimental research design; Cebu City; Philippines

1. Introduction

The Filipino "pasalubong" culture reflects a long-standing tradition of sharing gifts as a symbol of remembrance, generosity, and connection among loved ones. Rooted in the concept of salubong or welcoming, this practice goes beyond simple gift-giving and represents a meaningful way of expressing care and thoughtfulness [1]. Pasalubong items often include local delicacies that highlight regional identity, such as broas, dried mangoes, and other native products. These food items serve not only as souvenirs but also as cultural representations of specific places in the Philippines, making them valuable in both social and economic contexts.

At the same time, the increasing demand for coffee worldwide has led to a significant rise in food waste, particularly in the form of spent coffee grounds (SCG). SCG are the solid residues left after the brewing process and are commonly discarded despite containing beneficial components such as dietary fiber and antioxidants [2]. Globally, coffee production has reached approximately 168 million 60-kilogram bags, contributing to large volumes of SCG waste annually [3]. In the Philippines alone, coffee consumption reached 3.31 million bags in recent years, indicating a continuous rise in local demand [4]. While this growth supports the coffee industry, it also raises environmental concerns, as improper disposal of SCG contributes to landfill accumulation and greenhouse gas emissions.

Recent studies have explored the potential of utilizing food by-products like SCG in developing sustainable food products. Some researchers suggest that incorporating SCG into baked goods can enhance nutritional value and promote waste reduction, while others note that excessive amounts may affect sensory qualities such as taste and texture [5,6]. These differing findings highlight the need to carefully evaluate both the acceptability and feasibility of

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using SCG as a food ingredient. In this context, sensory evaluation becomes essential in determining whether such innovations are acceptable to consumers.

Therefore, this study aims to assess the acceptability of broas incorporated with varying levels of spent coffee grounds and to determine the feasibility of using SCG as a sustainable ingredient. By combining the Filipino tradition of pasalubong with food innovation and waste reduction, this research seeks to develop a product that is not only acceptable to consumers but also environmentally responsible. The findings of this study are expected to contribute to sustainable food production practices and provide an alternative way of utilizing coffee waste in the local setting.

2. Materials and Methods

This experimental research utilized a structured sensory evaluation to measure the acceptability of broas (ladyfingers) infused with Spent Coffee Grounds (SCG). The study adopted the Input-Process-Output (IPO) framework: the Input consisted of three distinct formulations of broas incorporated with varying levels of SCG; the Process involved sensory testing, feasibility assessments, and comprehensive statistical treatments, while the Output resulted in the final developed product representing a sustainable food innovation. The research was conducted at in one of the state universities in Cebu, Philippines, an ISO 9001:2015 certified institution. Specifically, the study took place within the College of Education, where the Food Service Management and Technology and Livelihood Education (TLE) programs provided the necessary technical environment to ensure the quality and consistency of the experimental production.

A total of 45 respondents were selected through purposive sampling to ensure the accuracy and reliability of the evaluation. This cohort was composed of 20 faculty members (44.44%) and 25 students specializing in food preparation (55.56%), all chosen for their professional familiarity with baked goods and culinary standards. During the selection process, the researchers ensured that participants had no known allergies to the core ingredients, such as eggs and wheat, to mitigate any potential health risks. The data-gathering procedure was structured into three phases: the Preliminary Stage, the Data Gathering Stage, and the Post-Data Gathering Stage. Before the actual tasting sessions began, respondents were thoroughly briefed on the objectives of the study. Strict ethical considerations were enforced through the administration of informed consent forms, which clearly stated that participation was entirely voluntary and that respondents reserved the right to withdraw at any point without prejudice. Furthermore, to uphold the highest standards of data privacy, all personal identifiers were anonymized, and the gathered data were stored in encrypted files to ensure confidentiality and protect the participants' right to privacy in accordance with the Data Privacy Act.

The sensory evaluation utilized a 9-point Hedonic Scale, where a score of 1 represented "Dislike Extremely" and 9 represented "Like Extremely," while the feasibility of the innovation was measured using a 5-point Likert Scale. During the evaluation, participants were provided with water as a palate cleanser between samples to prevent flavor carry-over and ensure the integrity of the sensory scores. The gathered data were analyzed using Frequency Counts and Weighted Means to determine the average preference scores for each attribute. Standard Deviation (SD) was also calculated to assess the consistency of the evaluators' ratings. To determine if there were significant differences among the three formulations (T1, T2, and T3), a One-way Analysis of Variance (ANOVA) was applied at a 0.05 significance level. Since significant variance was detected, a Bonferroni Post Hoc Test was conducted to compare the perceptions of the professionals against those of the students. Through this rigorous methodology, the transition of SCG from a waste product to a functional food ingredient was validated through a scientific process and consumer consensus, providing a robust foundation for sustainability in the food industry.

3. Results and Discussion

The following section presents the results and a comprehensive discussion of the data gathered during the assessment of spent coffee grounds (SCG) as a functional ingredient in Broas.

Based on the data presented in Table 1, Treatment 1 (T1) and Treatment 3 (T3) both achieved a weighted mean of 7.53, corresponding to a descriptive rating of "Like Very Much," while Treatment 2 (T2) was rated as "Like Moderately" with a mean of 6.96. Analysis of consistency revealed that T1 had the highest variety in scores (SD = 1.46), whereas T3 showed the most stable preferences with the lowest deviation (SD = 1.12), and T2 maintained a moderate level of consistency (SD = 1.21). These results indicate that both T1 (12g SCG) and T3 (36g SCG) are highly acceptable to consumers, proving that the inclusion of spent coffee grounds does not negatively impact the overall taste but rather introduces a unique, palatable flavor highly preferred by respondents.

Table 1 Taste

Treatment	n	Mn	SD	Verbal Interpretation
Treatment 1 (T_1)	45	7.53	1.46	Like Very Much
Treatment 2 (T_2)	45	6.96	1.21	Like Moderately
Treatment 3 (T_3)	45	7.53	1.12	Like Very Much

Legend: 8.12-9.00 Like Extremely (LE); 7.23-8.11 Like Very Much (VM); 6.34-7.22 Like Moderately (LM); 5.45-6.33 Like Slightly (LS); 4.56-5.44 Neither Like or Dislike (NLOD); 3.67-4.55 Dislike Slightly (DS); 2.78-3.66 Dislike Moderately (DM); 1.89-2.77 Dislike Very Much (DVM); 1.00-1.88 Dislike Extremely (DE)

Research indicates that Spent Coffee Grounds (SCG) can be successfully integrated into baked goods like shortbread biscuits and cookies without compromising flavor or perception. Studies show that samples containing up to 10% SCG maintain high sensory acceptability, mirroring current findings where moderate additions enhanced coffee flavor. According to previous studies, dehydrated SCG produces pleasant sensory profiles [7]. Furthermore, sensory perception and taste sensitivity significantly influence consumer preference [8], supporting Table 3 data where respondents' status as coffee enthusiasts directly informed their favorable numerical ratings of the broas.

Table 2 Aroma

Treatment	n	Mn	SD	Verbal Interpretation
Treatment 1 (T_1)	45	7.07	1.42	Like Moderately
Treatment 2 (T_2)	45	7.42	0.97	Like Very Much
Treatment 3 (T_3)	45	7.51	1.16	Like Very Much

Legend: 8.12-9.00 Like Extremely (LE); 7.23-8.11 Like Very Much (VM); 6.34-7.22 Like Moderately (LM); 5.45-6.33 Like Slightly (LS); 4.56-5.44 Neither Like or Dislike (NLOD); 3.67-4.55 Dislike Slightly (DS); 2.78-3.66 Dislike Moderately (DM); 1.89-2.77 Dislike Very Much (DVM); 1.00-1.88 Dislike Extremely (DE)

In Table 2, Treatment 3, which utilized 36 grams of spent coffee grounds, achieved the highest weighted mean for aroma at 7.51, a score interpreted by respondents as "Like Very Much." This finding confirms that higher concentrations of coffee residue significantly optimize the olfactory appeal of traditional broas by providing a balanced, inviting profile that is neither overpowering nor weak. Because the aromatic intensity directly shapes how flavors are perceived, the strong preference for this formulation suggests that aroma serves as a primary driver for consumer acceptance, often exerting more influence on product liking than taste alone. Consequently, maximizing the natural fragrance of the coffee.

Previous studies indicate that natural compounds in coffee residues enhance aroma [9]. Similarly, higher concentrations improve aromatic perception while maintaining product quality [10]. These external studies reinforce the current results, confirming that Treatment 3 effectively improves scent while maintaining a well-balanced and pleasing sensory experience in broas.

Table 3 Appearance

Treatment	n	Mn	SD	Verbal Interpretation
Treatment 1 (T_1)	45	7.40	1.33	Like Very Much
Treatment 2 (T_2)	45	6.73	0.97	Like Moderately
Treatment 3 (T_3)	45	6.76	1.37	Like Moderately

Legend: 8.12-9.00 Like Extremely (LE); 7.23-8.11 Like Very Much (VM); 6.34-7.22 Like Moderately (LM); 5.45-6.33 Like Slightly (LS); 4.56-5.44 Neither Like or Dislike (NLOD); 3.67-4.55 Dislike Slightly (DS); 2.78-3.66 Dislike Moderately (DM); 1.89-2.77 Dislike Very Much (DVM); 1.00-1.88 Dislike Extremely (DE)

Statistical analysis from Table 3 shows that Treatment 1 (12g SCG) achieved the highest weighted mean of 7.40, interpreted as "Like Very Much". In contrast, Treatment 2 (6.73) and Treatment 3 (6.76) were both rated as "Like Moderately". While Treatment 2 maintained the most consistent scores with a low standard deviation of 0.97, Treatment 1 remained the most acceptable to consumers. This indicates that broas with the least amount of SCG are

more aesthetically pleasing due to their lighter, traditional color, which enhances visual appeal without compromising the product's classic physical form.

Furthermore, these results imply that appearance serves as a critical quality signal that directly influences consumer expectations and final acceptance levels. Therefore, improving visual and aromatic attributes is essential, as these sensory factors collectively shape consumer preferences and can significantly increase the overall marketability of sustainable food innovations like SCG-enriched broas.

Table 4 Texture

Treatment	n	Mn	SD	Verbal Interpretation
Treatment 1 (T_1)	45	7.42	1.20	Like Very Much
Treatment 2 (T_2)	45	6.71	1.56	Like Moderately
Treatment 3 (T_3)	45	7.16	1.15	Like Moderately

Legend: 8.12-9.00 Like Extremely (LE); 7.23-8.11 Like Very Much (VM); 6.34-7.22 Like Moderately (LM); 5.45-6.33 Like Slightly (LS); 4.56-5.44 Neither Like or Dislike (NLOD); 3.67-4.55 Dislike Slightly (DS); 2.78-3.66 Dislike Moderately (DM); 1.89-2.77 Dislike Very Much (DVM); 1.00-1.88 Dislike Extremely (DE)

Table 4 reveals that Treatment 1 (T1) earned the highest sensory rating for texture with a weighted mean of 7.42, interpreted as "Like Very Much". In contrast, Treatment 2 (T2) and Treatment 3 (T3) received lower scores of 6.71 and 7.16, respectively, both falling under the "Like Moderately" category. While T3 showed the most consistency with a standard deviation (SD) of 1.15, T1 followed closely at 1.20. These numerical results conclusively identify Treatment 1 as the most acceptable formulation regarding the physical mouthfeel and structural consistency of the broas.

The data implies that incorporating 12 grams of SCG in Treatment 1 establishes an ideal balance between softness and crispiness. However, insoluble fiber in SCG can disrupt the gluten network and moisture distribution, potentially creating a coarser or grainier feel. Insoluble fiber from SCG affects texture and perceived graininess [11]. Consequently, while SCG is a viable sustainable ingredient, controlling particle size and concentration is essential to maintain the traditional cohesive structure and ensure high consumer acceptance levels.

Table 5 Overall Acceptability of Spent Coffee Grounds in Broas

Treatment	n	Mn	SD	Verbal Interpretation
Treatment 1 (T_1)	45	7.58	1.08	Like Very Much
Treatment 2 (T_2)	45	7.31	1.04	Like Very Much
Treatment 3 (T_3)	45	7.51	0.87	Like Very Much

Legend: 8.12-9.00 Like Extremely (LE); 7.23-8.11 Like Very Much (VM); 6.34-7.22 Like Moderately (LM); 5.45-6.33 Like Slightly (LS); 4.56-5.44 Neither Like or Dislike (NLOD); 3.67-4.55 Dislike Slightly (DS); 2.78-3.66 Dislike Moderately (DM); 1.89-2.77 Dislike Very Much (DVM); 1.00-1.88 Dislike Extremely (DE)

Table 5 shows that all three formulations achieved a "Like Very Much" rating for overall acceptability. Treatment 1 (T1) emerged as the most preferred option with the highest weighted mean of 7.58, despite a standard deviation of 1.08 indicating varied perceptions. Treatment 3 (T3) followed closely with a mean of 7.51 and the lowest standard deviation of 0.87, reflecting the most consistent respondent scores. Meanwhile, Treatment 2 (T2) received a weighted mean of 7.31 with an SD of 1.04. These numerical results confirm high consumer acceptance across varying SCG concentrations.

Furthermore, these high scores imply that a synergy of aroma, texture, and appearance drives overall product quality. Sensory attributes such as aroma and appearance influence overall acceptability. Although SCG introduced a slightly grainy texture, the mouthfeel remained pleasant. Additionally, SCG does not negatively affect texture perception [11]. Studies also confirm that upcycled ingredients maintain high acceptability [6], maintain excellent sensory qualities and high market acceptance in innovative baked goods.

Table 6 Summary on the Degree of Acceptability of Spent Coffee Grounds in Broas

Sensory Attributes	**TREATMENT**		
	T_1	T_2	T_3
Taste	7.53	6.96	7.53
Aroma	7.07	7.41	7.51
Appearance	7.40	6.73	6.76
Texture	7.42	6.71	7.16
Overall Acceptability	7.58	7.31	7.51
Average	7.40	7.02	7.29
Interpretation	VM	LM	VM

Legend: 8.12-9.00 Like Extremely (LE); 7.23-8.11 Like Very Much (VM); 6.34-7.22 Like Moderately (LM); 5.45-6.33 Like Slightly (LS); 4.56-5.44 Neither Like or Dislike (NLOD); 3.67-4.55 Dislike Slightly (DS); 2.78-3.66 Dislike Moderately (DM);1.89-2.77 Dislike Very Much (DVM); 1.00-1.88 Dislike Extremely (DE)

Statistical results from Table 6 indicate that Treatment 1 (T1) earned the highest level of consumer preference, achieving a 7.40 average weighted mean, which translates to a "Like Very Much" rating. Specifically, T1 outperformed other formulations in visual appearance (7.40), physical texture (7.42), and overall product acceptability (7.58). Treatment 3 (T3) followed with a 7.29 mean, showing particular strength in the aroma category with a peak score of 7.51. In contrast, Treatment 2 (T2) was the least favored, receiving a "Like Moderately" interpretation with a 7.02 average. These figures demonstrate that while every version was deemed acceptable, the 12-gram SCG concentration (T1) yielded the most harmonious sensory results.

Furthermore, Controlled incorporation of SCG preserves sensory quality [6]. The aromatic success of T3 revealed that coffee residues also enhance aroma [9], Moreover, the high texture ratings for T1—despite the inclusion of insoluble fiber— indicating that SCG can be a successful sustainable additive in traditional treats like broas while maintaining a desirable mouthfeel and structural quality [11].

Table 7 Feasibility of Incorporating Spent Coffee Grounds in Broas

No	**Indicators**	**Mn**	**SD**	**VD**
1	Incorporating SCG into broas is feasible and can be prepared through standard baking techniques.	4.22	0.93	SA
2	SCG can be added to broas in a safe manner without posing any health hazards.	4.09	0.82	A
3	Incorporating SCG into broas serves as a practical method to minimize food waste.	4.42	0.87	SA
4	Adding SCG to broas promotes sustainability and helps make the product more environmentally friendly.	4.56	0.81	SA
5	Broas made with SCG may be embraced by consumers in the market.	4.18	0.86	A
6	Adding SCG to broas has the potential to enhance its nutritional content.	4.16	0.82	A
7	SCG are a reliable ingredient that can be regularly obtained for baking broas	4.44	0.72	SA
	Overall	4.30	0.84	SA

Legend: 4.21-5.00 Strongly Agree (SA); 3.41-4.20 Agree (A); 2.61-3.40 Neutral (N); 1.81-2.60 Disagree (D); 1.00-1.80; Strongly Disagree (SD)

Table 7 confirm that all 45 participants strongly supported the practicality of integrating spent coffee grounds into broas, yielding a high overall weighted mean of 4.30. Respondents specifically prioritized environmental sustainability, as Statement 4 received the highest score of 4.56 for its focus on upcycling waste. High ratings for Statements 1, 3, and 7 further validate that SCG is viewed as a dependable, eco-friendly component suitable for standard baking techniques. These findings indicate a robust consensus that utilizing coffee industry by-products is a viable method for promoting sustainable food production.

Consequently, this data implies that the innovation successfully aligns with the modern shift toward food security through ingredient resourcefulness. While safety and nutritional potential received high "Agree" ratings, the overall positive impression suggests that SCG-enriched broas are market-ready, despite the need for further refinement. These results are bolstered by previous research, which emphasizes that incorporating upcycled coffee residues can be effectively incorporated without compromising quality [6]. By transforming a common byproduct into a value-added ingredient, this study offers a creative twist to traditional delicacies while significantly reducing environmental food waste.

Table 8 Significant Difference of Professional Responses and Students' Responses for Treatment 1= 12g of SCG in Broas

Source of Variation	SS	df	MS	F	p-value	Decision	F crit
Between Groups	0.87	1.00	0.87	10.76	0.02	Accepts H_1	Statistically Significant
Within Groups	0.49	6.00	0.08				
Total	1.36	7.00					

Note: Significant if the p-value < 0.05.

Using a one-way ANOVA for Treatment 1 (12g SCG), Table 8 reveals a significant difference between the evaluations of food professionals and students, as indicated by an F-value of 10.76 and a p-value of 0.02. This result supports the hypothesis that these two groups utilize distinct evaluative standards when assessing the sensory qualities of the product. The Between Groups sum of squares (0.87) notably exceeded the Within Groups sum (0.49), further confirming this statistical divergence. These findings suggest that the specific qualifications and specialized backgrounds of the respondents directly influenced their perceptions of the 12-gram formulation's overall acceptability.

Furthermore, the data implies that the professionals applied more consistent and rigorous criteria during the sensory evaluation compared to the students. This variation in judgment for Treatment 1 underscores how professional expertise can lead to more uniform sensory benchmarking in food innovation. Subjective sensory information and personal taste sensitivity have a profound impact on how individuals' rate and prefer food products (8). Consequently, the significant difference observed highlights that while the 12-gram concentration is highly acceptable, its perceived quality is sensitive to the observer's level of industry expertise.

Table 9 Post-hoc Pairwise Comparisons on the Significant Difference of *Professional Responses and Students' Responses for Treatment 1= 12g of SCG in Broas*

Groups	MN	p-value (adjusted)	Significance
Treatment 1: Professionals vs. Students	7.36	0.003	YES
Treatment 2: Professionals vs. Students	7.02	0.950	NO
Treatment 3: Professionals vs. Students	7.31	0.139	NO

Note: Significant if the p-value < 0.017.

Post-hoc analysis was performed in Table 9, based on the result it confirms that Treatment 1 (12g SCG) achieved the highest mean of 7.36, reinforcing its status as the most favored formulation. With an adjusted p-value of 0.003, which is significantly lower than the 0.017 threshold, the statistical difference between professional and student ratings is formally verified. In contrast, Treatment 3 and Treatment 2 yielded p-values of 0.139 and 0.950, respectively, indicating no significant divergence between the groups for these versions. These findings conclude that a lower concentration of coffee grounds results in higher overall acceptability and more distinct evaluative patterns among experts.

Furthermore, the data implies that as the concentration of SCG decreases, the sensory characteristics of the broas become more refined, leading to a sharper contrast in how professionals and students perceive quality. This disparity suggests that industry experts apply more stringent standards to the "ideal" formulation than non-professionals. This argues that subjective taste sensitivity and specialized background knowledge are pivotal in determining product preference levels [8]. Consequently, the success of Treatment 1 underscores that moderate upcycling effectively balances innovative flavor with traditional expectations regarding the preservation of crumb structure.

Table 10 Significant Difference of Professional Responses and Students' Responses for Treatment 2= 24g of SCG in Broas

SS	df	MS	F	P-value	Decision	F crit
0.004	1.00	0.004	0.02	0.88	Accepts H_0	Statistically Insignificant
0.92	6.00	0.15				
0.92	7.00					

Note: Significant if the p-value < 0.05.

The one-way ANOVA for Treatment 2 in Table 10, utilized 24 grams of spent coffee grounds, demonstrated a statistically insignificant difference between the ratings provided by food professionals and students. With an F-value of 0.02 and a p-value of 0.88, the data necessitates the acceptance of the null hypothesis, confirming that both respondent groups shared nearly identical perceptions of this specific formulation. The analysis showed that the Between Groups sum of squares (0.004) was considerably lower than the Within Groups sum (0.92), while the Mean Square followed a similar pattern. These metrics indicate that the 24-gram concentration failed to create any distinctive impact across different levels of expertise.

Furthermore, this lack of statistical variance implies that Treatment 2 possessed sensory characteristics that were consistently viewed as neither exceptionally favorable nor significantly polarizing by either group. The uniformity in these mediocre ratings suggests that at this specific concentration, the product's attributes do not strongly resonate with or offend the specialized standards of professionals or the academic criteria of students. This also indicates that when sensory information is not distinct enough to trigger strong subjective preferences, consumer ratings tend to converge regardless of background [8].

Table 11 Significant Difference of Professional Responses and Students Responses for Treatment 3= 36g of SCG in Broas

Source of Variation	SS	df	MS	F	P-value	Decision	F crit
Between Groups	0.30	1.00	0.30	2.33	0.18	Accepts H_0	Statistically Insignificant
Within Groups	0.78	6.00	0.13				
Total	1.09	7					

Note: Significant if the p-value < 0.05.

Statistical analysis in Table 11 using a one-way ANOVA for Treatment 3 (36g SCG) indicates that there was no significant difference between the ratings provided by industry professionals and food-related students. With an F-value of 2.33 and a p-value of 0.18, the results lead to the acceptance of the null hypothesis, confirming that both respondent groups perceived the 36-gram formulation similarly. Although the Between Groups Mean Square (0.30) was slightly higher than the Within Groups Mean Square (0.13), the total variance remained statistically negligible. This uniformity across taste, aroma, appearance, and texture suggests a shared sensory perspective regarding the highest concentration of spent coffee grounds.

These findings suggest that when the concentration of spent coffee grounds is higher, the sensory profile becomes so distinct that professional expertise no longer creates a gap in judgment. This consensus between students and industry experts implies that the bold coffee characteristics of Treatment 3 offer a uniform experience that transcends the evaluator's background. This is noted that higher levels of coffee by-products typically produce a more cohesive flavor and aroma that is easily recognizable by all consumers [10]. Ultimately, the lack of a statistical difference proves that Treatment 3 is a dependable formulation, capable of appealing to various people regardless of their culinary training.

4. Conclusion

The study, "Assessing the Acceptability of Spent Coffee Grounds in Broas: A Sustainable Innovation," concludes that Treatment 1 (12g SCG) is the optimal formulation, achieving a 7.58 weighted mean. Respondents strongly affirmed the feasibility of this upcycled delicacy, yielding a 4.30 average. This alignment with sustainable production goals confirms that SCG effectively enhances traditional baking while reducing waste. Moving forward, researchers recommend

conducting technology transfers to local entrepreneurs and performing detailed nutritional analyses to confirm antioxidant retention. Future studies should also include broader consumer market testing and economic feasibility assessments to ensure commercial scalability and long-term industrial viability.

Compliance with ethical standards

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Disclosure of conflict of interest

There was no conflict of interest to be disclosed.

Statement of ethical approval

This study was conducted in accordance with ethical standards for research involving human participants. Ethical review and formal approval were not required as the study involved voluntary participation, posed minimal risk, and did not include any sensitive or invasive procedures. The research was carried out following institutional guidelines of one of the state universities in Cebu, Philippines.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study prior to data collection. Participants were informed of the study's objectives, procedures, and their rights, including confidentiality and voluntary participation.

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