

Enhancing Consumer Acceptance of Zero-Waste Food through Education: A Study on Banana Stem Chips in Indonesia

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Abstract

Banana cultivation in Indonesia generates substantial agricultural waste, particularly from banana stems, which are typically discarded despite their nutritional potential. This study examined whether a targeted educational intervention could influence consumer sensory acceptance of banana stem chips, a zero-waste food innovation derived from banana pseudostems (*Musa paradisiaca*). A quasi-experimental single-group pre-test and post-test design was conducted with 221 domestic tourists in Yogyakarta and Malang. Participants evaluated six sensory attributes (aroma, appearance, color, taste, texture, and overall impression) using a five-point hedonic scale (1 = strongly dislike; 5 = strongly like). The measurement instrument demonstrated satisfactory internal consistency (Cronbach's $\alpha = 0.853$ pre-test; 0.795 post-test). Following the pre-test, participants attended a 5–10 minute educational session featuring posters and verbal explanations that highlighted the nutritional benefits, zero-waste principles, and environmental implications of banana stem utilization. Paired-sample *t*-tests revealed statistically significant improvements across all sensory attributes after the intervention ($p < 0.01$). The largest mean increase was observed for taste (+0.68), followed by aroma (+0.55) and overall impression (+0.55), while appearance (+0.45), texture (+0.46), and color (+0.36) also improved significantly. These findings indicate that brief sustainability and nutrition-oriented information can positively influence sensory evaluations of unconventional, waste-derived food products, even when the product formulation remains unchanged. The results provide empirical evidence that educational framing can reduce perceptual barriers to suboptimal foods and support the market introduction of zero-waste innovations in emerging economies.

Keywords: Banana stem chips; Consumer education; Suboptimal food; Sensory evaluation; Zero-waste innovation

1 Introduction

Bananas (*Musa paradisiaca*) are cultivated intensively in Indonesia due to favorable climatic conditions and high demand. Over 200 distinct varieties of bananas are cultivated in In-

donesia (De Langhe et al., 2009; Yudha & Norbayinda, 2023). Indonesia possessed 188,488 hectares of land designated for banana cultivation in 2022 (Food and Agriculture Organization of the United Nations, 2023). However,

this intensive production generates a substantial volume of agricultural waste. Postharvest processing focuses largely on the fruit. Other plant components, particularly stems and leaves, are typically discarded, contributing to agricultural waste, despite their potential utility (Arifki & Barliana, 2018; Ekayanti et al., 2023). The biomass waste poses considerable environmental challenges, including soil degradation, greenhouse gas emissions, and water contamination from leachate (Meilani & Susyani, 2021; Wikurendra et al., 2023).

A transition towards a circular economy offers a strategic pathway to address the challenge by transforming agricultural byproducts into value-added resources. This approach aligns with the “7R framework” (Rethink, Refuse, Reuse, Repurpose, Recycle, and Rot), which promotes optimal resource utilization and minimal environmental impact (Vinkóczy et al., 2023). Banana stems, often discarded, offer a significantly underutilized resource. Rich in cellulose and dietary fiber, banana stems offer nutritional advantages, including digestive assistance and blood glucose regulation (Sumbawati et al., 2023). Thus, transforming banana stems into innovative food products, such as banana stem chips, offers a significant opportunity to reduce agricultural waste, generate new economic value, and enhance the sustainability of Indonesia’s food system (Krungkaew et al., 2023).

Food products derived from agricultural byproducts are frequently categorized as suboptimal foods, a term referring to foods produced from unconventional ingredients or typically considered waste, such as irregularly shaped vegetables or, in this instance, agricultural byproducts (Aschemann-Witzel et al., 2015; Szymkowiak et al., 2024). Suboptimal foods often face significant consumer resistance. Consumer reluctance frequently stems from perceptual biases, lack of knowledge, and negative associations with waste, which constitute significant obstacles to market acceptance (Szymkowiak et al., 2024). Addressing these psychological obstacles is important for effectively marketing suboptimal food products, such as banana stem chips.

Consumer resistance to suboptimal foods primarily stems from cognitive, attitudinal, and social perceptions rather than objective prod-

uct characteristics. Therefore, addressing these challenges requires more than technical improvements. A behavioral perspective is essential for understanding how consumers develop preferences and make acceptance decisions, especially when faced with unconventional food sources. This study utilizes two complementary behavioral theories. The Theory of Planned Behavior (TPB) asserts that consumer acceptance is influenced by attitudes (positive or negative perspectives on the product), subjective norms (social influences), and perceived behavioral control (confidence in trying the product) (Ajzen, 1991). Importantly, these aspects are dynamic and can be influenced through the dissemination of knowledge and information. Rogers’ Diffusion of Innovation theory supports this concept by highlighting that knowledge is a crucial determinant of product acceptance (Rogers, 2003). This study posits that a targeted educational intervention that provides information on the nutritional benefits, zero-waste principles, and environmental consequences can strengthen all three components of the Theory of Planned Behavior, thereby enhancing consumer acceptance of banana stem chips. Research by Aschemann-Witzel et al. (2015) and Lagerkvist et al. (2023) demonstrates that education can improve consumer attitudes towards sustainable products, create more favorable subjective norms by highlighting sustainability benefits, and increase perceived control by reducing uncertainty, thereby enhancing sensory acceptance.

Although previous research suggests that educational strategies can enhance perceptions of sustainable foods (Aschemann-Witzel et al., 2015), a significant gap exists in the literature regarding their specific influence on consumer acceptance of zero-waste products derived from agricultural by-products, particularly in developing countries such as Indonesia. There is a lack of empirical evidence about the effectiveness of targeted information in mitigating sensory biases towards suboptimal foods. This study addresses this gap by providing a quantitative analysis of changes in consumer sensory evaluation following a targeted educational intervention.

This research aims to address the following question: To what extent does a targeted educational intervention influence consumers’ sensory

acceptance of banana stem chips? This study aims to empirically validate the essential role of consumer education in linking sustainable food innovation with market behavior. The results are anticipated to yield significant insights for sustainability educators, food entrepreneurs, and policymakers in Indonesia, offering an adaptable framework to enhance the consumption of zero-waste foods and strengthen the principles of a circular economy within the banana value chain.

2 Materials and Methods

2.1 Study design and participants

This study used a quasi-experimental single-group pre-test and post-test design to examine changes in consumer sensory acceptance of banana stem chips following a targeted educational intervention. This approach enabled within-subject comparison, allowing each participant to serve as their own control and thereby reducing inter-individual variability in sensory perception attributable to personal preferences or background characteristics. The study was conducted in 2024 in two Indonesian cities, Yogyakarta and Malang, which were selected purposively for their high levels of tourism activity and exposure to culinary innovation.

Participants were domestic tourists encountered at public tourism destinations and culinary areas. Recruitment was conducted using a direct, on-site convenience sampling approach, in which individuals at the study locations were informed of the study's objectives and procedures. Those who expressed willingness to participate were screened for eligibility prior to enrollment.

Participants were required to be at least 16 years old, have no known allergies to banana products or to the ingredients used in the chips (wheat flour, rice flour, salt, etc.), and be willing to participate in both the pre-test and post-test sensory evaluations. A total of 221 participants completed both the pre-test and post-test sensory evaluations, with no recorded dropouts. This sample size exceeds commonly cited recommendations in consumer sensory research, as studied by Mammasse and Schlich (2014), indicating that hedonic consumer tests typically re-

quire approximately 50–100 untrained consumers to obtain reliable acceptability data, depending on product complexity and test design. The number of participants in this study, therefore, provides sufficient statistical power for paired sample comparisons.

2.2 Product preparation

Banana stems (*Musa paradisiaca*) were obtained from the “Amanah” Women Farmer Group located in the Special Region of Yogyakarta, Indonesia. The stems were sourced from local Indonesian banana varieties and collected immediately after fruit harvesting. For processing, the 6th to 7th outer layers of the banana pseudostem were selected, as these layers possess suitable textural properties and fiber content for chip production. All banana stem chips were prepared using a standardized and consistently applied procedure to ensure sample uniformity throughout the study.

The banana stems were first washed thoroughly under running water to remove dirt and impurities, then sliced into pieces approximately 5 mm to 10 mm thick and 3 cm to 5 cm long. The sliced stems were subsequently soaked for 30 min in a solution containing salt and lime (calcium hydroxide) to eliminate sap, reduce bitterness, and improve the final texture. After soaking, the stems were drained and coated with a batter composed of wheat flour, rice flour, and natural seasonings, including salt, garlic powder, and turmeric, using a dipping method.

The coated stem slices were deep-fried in vegetable oil at 170 °C to 180 °C for 3–5 minutes, until they were crispy and golden brown. Excess oil was removed using absorbent paper, after which the chips were allowed to cool at room temperature for approximately 10–15 minutes. The cooled chips were then packaged in sealed transparent plastic containers prior to sensory evaluation. All samples were prepared in a single batch to minimize batch-to-batch variation, and basic quality control was performed through visual inspection of color, texture, and moisture consistency before testing. The packaged samples were stored at room temperature (25 °C to 27 °C) in sealed containers and evaluated within

24 h of preparation to maintain product freshness and quality.

2.3 Sensory evaluation

Consumer sensory acceptance was assessed using a structured questionnaire that evaluated six organoleptic attributes: aroma, appearance, color, taste, texture, and overall impression. Each attribute was rated using a five-point hedonic Likert scale, ranging from 1 (*strongly dislike*) to 5 (*strongly like*). Prior to data analysis, the instrument underwent psychometric evaluation, including reliability testing and item validity assessment. Reliability was examined using Cronbach's alpha, while item validity was evaluated through item total correlation analysis. The results indicated that the instrument demonstrated acceptable internal consistency and validity, with Cronbach's alpha exceeding 0.70 for both the pre-test and post-test.

Sensory evaluations were conducted outdoors at tourism locations, reflecting natural consumption environments commonly encountered by consumers. No environmental conditioning, such as controlled lighting or temperature, was applied during testing. Each participant received one portion of banana stem chips served on a plain plate and was instructed to evaluate the attributes sequentially, beginning with aroma and ending with overall impression. Drinking water was provided to cleanse the palate between evaluations.

The sensory evaluation was conducted as an open (unblinded) test, as participants were aware of the product being evaluated, and all participants received samples prepared from the same production batch. To enable paired statistical analysis, individual pre-test and post-test responses were linked using unique participant identification codes, ensuring accurate matching of sensory evaluations before and after the educational intervention.

2.4 Educational intervention

The educational intervention was designed to provide concise, targeted information on the use of banana stems as food ingredients, the nutritional and functional benefits of banana stem

chips, the principles of zero-waste food processing, and the environmental and socio-economic benefits of agricultural waste valorization. The intervention was conceptually grounded in the Theory of Planned Behavior (Ajzen, 1991) and the Diffusion of Innovation Theory (Rogers, 2003), which emphasize the role of knowledge in shaping consumer attitudes, perceived behavioral control, and the adoption of innovative food products.

Immediately after completing the pre-test sensory evaluation, participants attended a brief group educational session lasting approximately 5–10 minutes. Group size varied depending on the number of respondents present at each study location. The session consisted of a short visual explanation using posters or infographics (approximately 2–4 minutes), followed by a verbal explanation delivered by a trained member of the research team (approximately 3–6 minutes). The intervention followed a standardized set of key messages to ensure consistency across sessions. The post-test sensory evaluation was conducted immediately after the educational intervention, allowing assessment of changes in sensory acceptance attributable to the information provided.

2.5 Statistical analysis

IBM SPSS Statistics version 21.0 was used to conduct data analysis. Respondent characteristics and preference scores were summarized to determine whether there were statistically significant differences in mean acceptability scores before and after the educational intervention; a paired-samples *t*-test was used. The significance level was established at $\alpha = 0.01$. Cronbach's alpha values exceeding 0.70 indicated satisfactory internal consistency, which validated the measurement instrument's reliability.

3 Results and Discussion

3.1 Sample characteristics

A total of 221 domestic tourists participated in the study, with a relatively balanced gender distribution (51.58% female and 48.42% male). The largest age group was 16–25 years (42.99%), followed by 26–35 years (20.81%) and 46–55 years

(18.55%), indicating a predominance of young and working-age adults. This demographic profile is relevant, as younger consumers are generally more exposed to sustainability narratives and novel food experiences (Van Loo et al., 2011).

Regarding education, 46.61% of respondents had completed high school, and 41.63% held a bachelor's degree, while only a small proportion reported elementary-level education (2.26%) or postgraduate degrees (2.71%). Education level is frequently associated with greater awareness of sustainability-related information and openness to unconventional food products.

Most respondents were students (29.41%) or private-sector employees (28.51%), followed by self-employed individuals (19.91%) and civil servants (5.88%). Monthly income levels were mainly within IDR 1.5–3.0 million (26.70%) and IDR 4.5–6.0 million (23.53%), corresponding approximately to USD 95–190 and USD 285–380, respectively (2025 exchange rates). These figures indicate moderate purchasing power and price sensitivity, important contextual factors for interpreting acceptance levels of innovative snack products derived from agricultural by-products.

3.2 Instrument validity and reliability

The internal consistency of the sensory evaluation instrument was assessed using Cronbach's alpha. The results indicated good reliability both before ($\alpha = 0.853$) and after ($\alpha = 0.795$) the educational intervention, exceeding the commonly accepted threshold of 0.70 for hedonic scales. Item–total correlations were statistically significant for all six sensory attributes ($r > 0.60$; $p < 0.01$), confirming satisfactory internal consistency and convergent validity. These results indicate that the five-point hedonic scale reliably captured consumer perceptions across sensory attributes and was suitable for evaluating changes in acceptance associated with the educational intervention.

3.3 Impact of education on sensory acceptance

Since banana stem chips are produced from an unconventional agricultural by-product, they can be classified as *suboptimal foods*, for which consumer expectations are often relatively low before exposure to information. Such expectations may influence initial sensory evaluations, particularly for attributes closely linked to perceived quality, such as taste and aroma. Although banana stems are often considered agricultural waste or repurposed for animal feed, recent research has shown that they have the potential to serve as an alternative raw material for culinary products due to their high fiber and mineral content (Imran & Indriani, 2022). Banana stems are largely discarded post-harvest, despite their nutritional benefits, indicating wasted opportunities in circular bioeconomy and zero-waste initiatives (Krungkaew et al., 2023).

Banana stems possess many health-related functional properties. Bioactive compounds found in banana stem tissue have the potential to improve glycemic control, weight management, and digestive health, thereby enhancing their value as a functional food (Sumbawati et al., 2023). Nevertheless, converting banana stems from waste into a food product necessitates overcoming cognitive and sensory barriers among consumers, particularly those associated with the perception and acceptance of suboptimal foods.

Banana stem chips are considered suboptimal products because their primary ingredient is derived from an unconventional source. Consumers generally associate suboptimal food with negative attributes such as inferiority, waste, or spoilage unless it is rebranded effectively with cues that emphasize sustainability, health benefits, and taste (Szymkowiak et al., 2024). The banana stem chips that were developed in this research were designed to resemble common snack items in both appearance and texture. They have a crispy consistency and a golden-brown color. These visual and sensory qualities significantly reduce the psychological distance between suboptimal constituents and desirable products (Aschemann-Witzel et al., 2015; Priya & Alur, 2023).

Table 1: Mean scores ($\pm$ standard deviation), t -values, and significance levels for sensory attributes of banana stem chips before and after the educational intervention ($n = 221$). All differences are statistically significant at the 1% level ($p < 0.01$).

Attribute	Pre-education	Post-education	t -value	Sig. (2-tailed)
Aroma	2.89 ± 0.93	3.44 ± 0.94	-9.81	0.001**
Appearance	3.02 ± 0.90	3.47 ± 0.87	-8.35	0.001**
Color	3.23 ± 0.94	3.59 ± 0.92	-6.89	0.001**
Taste	2.87 ± 1.02	3.55 ± 1.00	-10.97	0.001**
Texture	2.96 ± 0.92	3.42 ± 0.98	-7.22	0.001**
Overall impression	2.97 ± 0.83	3.52 ± 0.86	-9.29	0.001**
Total	17.97	20.99	-12.02	0.001**

Note: Values are mean $\pm$ standard deviation. **Significant at $p < 0.01$.

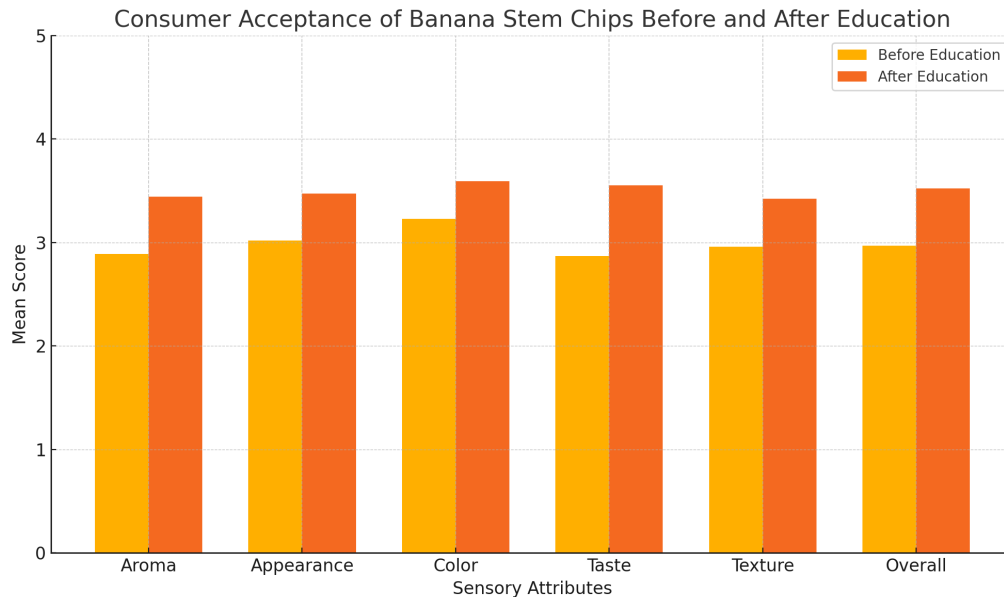


Figure 1: Comparison of mean sensory scores for banana stem chips before and after the educational intervention across six attributes: aroma, appearance, color, taste, texture, and overall impression. All attributes showed statistically significant improvement ($p < 0.01$).

The paired-sample t -test results (Table 1) show that all six sensory attributes increased significantly after the educational intervention ($p < 0.01$). Taste exhibited the largest mean change (+0.68), followed by aroma (+0.55) and overall impression (+0.55). Appearance (+0.45), texture (+0.46), and color (+0.36) also improved significantly, although to a lesser extent (Figure 1). These results indicate a consistent positive shift in consumer evaluations across sensory dimensions following the intervention.

Rather than focusing on individual numer-

ical values, the overall pattern suggests that sustainability- and nutrition-oriented information can positively influence how consumers perceive unfamiliar, waste-derived food products. In particular, the stronger improvement observed in taste and overall liking suggests that cognitive framing may partially counteract initial skepticism toward suboptimal foods. This finding aligns with prior research showing that sustainability-related communication can shape taste expectations and overall product evaluation, especially when consumers lack

prior experience with the product (Ajzen, 1991; Aschemann-Witzel et al., 2015; Rogers, 2003; Stone & Sidel, 2004; Szymkowiak et al., 2024).

From a behavioral perspective, the observed changes are consistent with the Theory of Planned Behavior and the Diffusion of Innovation framework. The educational intervention likely contributed to more favorable attitudes by highlighting environmental and nutritional benefits, reducing uncertainty related to product safety and processing (perceived behavioral control), and implicitly reinforcing positive social norms around sustainable consumption. Together, these mechanisms may explain why sensory acceptance increased even though the product's physical properties remained unchanged.

3.4 Theoretical and practical implications, and limitations

The findings provide empirical support for the role of educational interventions in shaping consumer responses to zero-waste food innovations. From a theoretical standpoint, the results illustrate how knowledge-based interventions can influence sensory evaluations indirectly by modifying cognitive and attitudinal factors, as proposed by the Theory of Planned Behavior and Rogers' Diffusion of Innovation theory.

From a practical perspective, the post-intervention overall acceptance score of approximately 3.5 on a five-point scale suggests moderate liking, indicating potential for market entry but also room for further product refinement and repeated exposure. Low-cost educational tools, such as posters or infographics highlighting the nutritional value, environmental benefits, and local economic contributions of banana stem chips, may therefore support early-stage commercialization of banana stem chips, particularly among young urban consumers in Indonesia.

Several limitations should be acknowledged. First, the absence of a control group limits causal inference about the intervention's exclusive effect. Second, the evaluation captured short-term responses immediately after the intervention, and longer-term acceptance or repeated purchase behavior was not assessed. Finally, although statistically significant, the observed ef-

fect sizes were modest, suggesting that education alone may not be sufficient to ensure widespread adoption without complementary product and marketing improvements.

4 Conclusions

This study examined the short-term effect of a targeted educational intervention on consumer sensory acceptance of banana stem chips, a zero-waste food product derived from agricultural by-products. Using a single-group pre-test and post-test design, the results show that sensory evaluations across all six attributes—aroma, appearance, color, taste, texture, and overall impression—increased significantly after the intervention. However, the observed changes were moderate in magnitude, ranging from 0.36 to 0.68 points on a five-point hedonic scale.

These findings suggest that consumer perceptions of suboptimal foods are not fixed and can be positively influenced by information highlighting sustainability, nutritional value, and processing transparency. In line with the Theory of Planned Behavior and the Diffusion of Innovation framework, the educational materials likely contributed to more favorable attitudes, reduced uncertainty, and greater openness toward tasting and evaluating an unfamiliar, waste-derived product. Importantly, the product's physical characteristics remained unchanged, indicating that the improvements in sensory acceptance were primarily driven by cognitive and informational factors.

From a practical perspective, an overall acceptance score of approximately 3.5/5 after the intervention indicates moderate liking, suggesting initial market potential rather than immediate mass adoption. Low-cost educational tools, such as posters or infographics emphasizing environmental, nutritional, and local economic benefits, may therefore support the early-stage introduction of banana stem chips among young urban consumers in Indonesia. These insights are particularly relevant for food entrepreneurs, sustainability educators, and policymakers seeking to promote circular economy strategies within banana value chains.

Several limitations should be acknowledged. The absence of a control group limits causal inference about the intervention's exclusive effect, and the short-term nature of the assessment does not capture sustained acceptance or repeated purchase behavior. Additionally, the moderate absolute liking scores indicate that educational interventions alone may be insufficient without parallel improvements in product formulation, branding, or repeated consumer exposure.

Overall, this study provides empirical evidence that targeted education can support consumer acceptance of zero-waste food innovations in a developing country context. Future research should incorporate control groups, longer follow-up periods, and behavioral outcomes such as willingness to pay or purchase intention to better assess the durability and economic relevance of education-driven acceptance effects.

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