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Upcycling Underutilized Food Resources: Development of Ready-to-Eat Dehydrated Spicy Papaya (*Carica Papaya*) Pickle

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Abstract

This study developed and evaluated a Ready-to-Eat Dehydrated Spicy Papaya (Carica papaya) Pickle fortified with Rice-Based Sagip Nutri-Powder as a value-added product for underutilized green papaya. Grounded in food innovation, preservation, nutritional fortification, sensory evaluation, and circular economy principles, the study employed an experimental research design using five formulations (F0–F4) with varying papaya levels and constant proportions of the other ingredients. Seventy-five respondents composed of students, faculty, staff, and untrained Food Technology experts participated in the sensory evaluation using a structured 9-point hedonic scale covering color/appearance, odor/aroma, taste/flavor, chewiness, and general acceptability. Proximate nutritional analysis, shelf-life assessment, Acceptability Consumers Index (ACI), and return on expenses (ROX) analysis were also conducted. Findings showed that increasing papaya content improved nutritional quality by increasing fiber, carbohydrates, energy, and ash content while reducing moisture, which supported better shelf stability. Significant differences were found among formulations in all sensory attributes, with F2 emerging as the most preferred formulation based on general acceptability and ACI. Shelf-life results showed that all formulations remained acceptable for seven days, with F2 demonstrating the greatest stability. Economic analysis revealed that higher papaya content increased production cost and reduced profitability, although F2 provided the most practical balance between acceptability and viability for commercialization. The study concludes that fortified dehydrated papaya pickle is a feasible product for food waste reduction, nutritional enhancement, and livelihood development, and recommends longer shelf-life testing, broader consumer validation, and further formulation refinement. The study is directly connected to SDG 2 (Zero Hunger) through food-based nutritional improvement and SDG 12 (Responsible Consumption and Production) through the upcycling of underutilized papaya and reduction of food waste. It also reflects a sustainability impact by supporting resource-efficient food utilization, improving access to nutrient-enhanced products, and offering potential livelihood and commercialization opportunities for local communities.

Keywords: Acceptability Consumers Index; Carica Papaya; Food Waste Reduction; Nutritional Fortification; Papaya Upcycling; Proximate Analysis; Ready-To-Eat Dehydrated Spicy Papaya Pickle; Sensory Acceptability; Shelf-Life Stability

1. Introduction

Food waste remains a major global and local concern, particularly in developing countries, affecting food systems from production to disposal and requiring collective action across stakeholders (Food and Agriculture Organization of the United Nations, 2023). In the Philippines, papaya (Carica papaya) is widely cultivated yet frequently wasted due to surplus production and aesthetic imperfections, leading to economic and environmental challenges. This study explores the transformation of underutilized green papaya into a Ready-to-Eat Dehydrated Spicy Papaya Pickle fortified with Rice-Based Sagip Nutri-Powder, integrating food innovation, sustainability, and livelihood development (Organisation for Economic Co-operation and Development, 2021).

1.1 Background of Papaya (Carica papaya) Upcycling and Fortified Food Product Development

Papaya (Carica papaya) is a nutrient-rich tropical fruit with historical, cultural, and medicinal significance, originating from Mesoamerica and spreading globally through colonization and trade (Chávez-Pesqueira & Núñez-Farfán, 2017; Encyclopaedia Britannica, 2026; Food and Agriculture Organization, 2020). It contains essential nutrients, antioxidants, and bioactive compounds beneficial for digestion, immunity, and overall health (Ali et al., 2011; Koul et al., 2022). Despite its value, significant portions of papaya remain underutilized. In the Philippine context, rice-based nutritional interventions such as Rice-Based Sagip Nutri-Powder have been developed to address malnutrition through locally available ingredients, supporting vulnerable populations. Integrating papaya with such nutrient-dense supplements offers an opportunity to enhance both food utilization and nutritional outcomes.

1.2 Key Literature on Food Product Development, Sensory Acceptability, and Papaya Processing

Literature emphasizes systematic food product development involving formulation, sensory evaluation, and testing to ensure quality, safety, and consumer acceptance (Moskowitz & Beckley, 2012). Dehydration and pickling are established preservation methods that reduce moisture, inhibit microbial growth, and extend shelf life (Barbosa-Cánovas & Vega-Mercado, 2020; Steinkraus, 2018). Papaya has been successfully processed into various value-added products such as dried foods and pickles, maintaining its nutritional properties. Nutritional enhancement through fortification improves dietary quality and addresses deficiencies (Zimmermann & Hurrell, 2008), while proximate analysis ensures accurate evaluation of food composition (Nielsen, 2010). Sensory evaluation using structured methods such as the 9-point hedonic scale and Acceptability-Consumer Index (ACI) is essential in determining consumer preferences (Amerine, Pangborn, & Roessler, 1965; Meilgaard, Civille, & Carr, 2016; Butt et al., 2017). Formulation optimization plays a critical role in balancing sensory quality, nutrition, and stability (Fellows, 2017; Myers & Montgomery, 2016). Shelf-life studies confirm that dehydration and pickling significantly enhance product stability and safety (Cruz, 2025; Choosuk et al., 2022; Sinchaipanit et al., 2022). Additionally, commercialization requires cost and profitability analysis to ensure economic viability (Sharma, 2018; Kumar & Singh, 2020; Hisrich, Peters, & Shepherd, 2017).

1.3 Local, National, and Global Practices in Papaya-Based Food Innovation and Utilization

Globally, various countries have developed innovative papaya-based products reflecting cultural diversity and food innovation. Examples include Philippine atchara (Pineda, 2023), Thai Som Tum (Pengiad, 2024), Vietnamese Gòi du dú (Flyziver, 2025), and Indonesian rujak (Ying Reinhardt, 2022). International initiatives also promote papaya waste utilization through partnerships and product development (Askew, 2021). Research in Brazil further demonstrates preservation techniques using edible coatings (Bakhla, R., Joseph, A. V., & Topno, S., 2023). Locally, rice-based nutritional programs such as BIDANI and PNEA support community nutrition and food innovation. These initiatives highlight the importance of integrating local resources with scientific approaches to address food security and malnutrition challenges.

1.4 Theoretical Basis of Food Innovation, Preservation, and Consumer Acceptability

The study is grounded in principles of food science, sustainability, and product development. Food innovation theory emphasizes transforming raw materials into value-added products through systematic processes (Moskowitz & Beckley, 2012). Preservation theories highlight dehydration and pickling as effective methods for ensuring food safety and longevity (Barbosa-Cánovas & Vega-Mercado, 2020; Steinkraus, 2018). Nutritional theory supports fortification as a strategy to improve dietary intake (Zimmermann & Hurrell, 2008), while sensory evaluation theory explains how product attributes influence consumer acceptability (Meilgaard, Civille, & Carr, 2016). Additionally, circular economy principles underpin the upcycling of food waste into valuable products, promoting resource efficiency and sustainability.

1.5 Research Gaps in Upcycling Papaya with Nutritional Fortification and Product Acceptability

Despite existing studies on papaya processing and food preservation, limited research integrates upcycling of underutilized papaya with dehydration, pickling, and nutritional fortification in a single ready-to-eat product. Variability in consumer preferences, product formulation, shelf-life conditions, and ingredient availability presents challenges that require systematic investigation. There is also a need to evaluate sensory acceptability, nutritional composition, shelf stability, and economic feasibility simultaneously. Addressing these gaps justifies the development of Ready-to-Eat Dehydrated Spicy Papaya Pickle fortified with Rice-Based Sagip Nutri-Powder as a comprehensive solution to food waste, nutrition, and livelihood concerns.

1.6 Alignment of Papaya Upcycling and Fortified Food Innovation with Sustainable Development Goals (SDGs)

This study aligns with several SDGs. It supports SDG 2 (Zero Hunger) by improving access to nutritious food through value-added products. It contributes to SDG 12 (Responsible Consumption and Production) by reducing food waste and promoting efficient resource use. It advances SDG 13 (Climate Action) by minimizing environmental impacts associated with food waste. Additionally, it supports SDG 8 (Decent Work and Economic Growth) by creating livelihood opportunities for farmers and small-scale producers (Organisation for Economic Co-operation and Development, 2021).

1.7 Multidisciplinary Sustainability Contributions of Ready-to-Eat Dehydrated Spicy Papaya Pickle Development

This study contributes to multiple sustainability domains. It promotes socio-economic sustainability by generating income opportunities and supporting rural livelihoods. It enhances food and nutritional sustainability by improving access to nutrient-rich products. It supports environmental sustainability by reducing waste and encouraging circular food systems. Furthermore, it contributes to educational and technological sustainability by integrating food science, product development, and innovation into research and practice. The findings may inform policies, curriculum development, and community-based programs, reinforcing sustainable food systems and local economic growth.

2. Material and methods

2.1 Research Design

The study employed an experimental research design using five formulations (F0–F4) with varying levels of papaya while maintaining constant proportions of other ingredients. The design integrated product development, sensory evaluation, proximate nutritional analysis, shelf-life assessment, and return on expenses (ROX) analysis to identify the most acceptable and economically viable formulation.

2.2 Locale of the Study

The study was conducted at Isabela State University–Echague Campus, where product preparation and sensory evaluation were performed. The proximate nutritional analysis was carried out at Quirino State University–Diffun Campus to determine the nutritional composition of the developed product.

2.3 Respondents of the Study

The respondents consisted of seventy-five (75) individuals composed of untrained students, faculty, staff, and untrained Food Technology experts. Participants were assessed based on their lifestyle, well-being, and current health status before participating in the sensory evaluation.

2.4 Sample and Sampling Procedure

A random sampling technique was used to select the seventy-five (75) respondents who participated in the sensory evaluation. Each respondent evaluated all five formulations. To ensure the validity and reliability of the results, participants were instructed to rinse their mouths before testing each sample.

2.5 Research Instrument

The study utilized a structured sensory evaluation tool based on the 9-point hedonic scale to assess color/appearance, odor/aroma, taste/flavor, chewiness, and general acceptability. This scale provided descriptive ratings ranging from “dislike extremely” to “like extremely,” allowing quantitative assessment of consumer preferences. Proximate nutritional analysis was conducted using standard laboratory methods, including Moisture Analyzer for moisture content, Raghuramalu method for ash, fiber, and carbohydrates, Folch method for lipid content, Biuret Method for protein, and Randive method for metabolized energy. The Acceptability Consumers Index (ACI) was also used to determine overall consumer preference by combining weighted sensory scores.

2.6 Data Gathering Procedure

The study began with the collection and preparation of materials, where underutilized green papaya was cleaned, peeled, sliced, and combined with measured ingredients. The preparation involved cutting the vegetables into uniform strips, brining them with non-iodized salt, rinsing, and draining before mixing with seasoning paste. The mixture was fermented at room temperature and then dehydrated using a food dehydrator at controlled temperatures until the desired moisture content was achieved. The product was then cooled and packed in airtight containers. The Rice-Based Sagip Nutri-Powder, developed through institutional initiatives, was incorporated as a fortification component. Sensory evaluation was conducted after product preparation, where respondents assessed each formulation under controlled conditions. Proximate nutritional analysis was performed in the laboratory, and cost data were gathered for economic evaluation.

2.7 Data Analysis Techniques

Data from sensory evaluation were tabulated, analyzed, and interpreted using descriptive statistics such as mean and qualitative descriptions. A one-way Analysis of Variance (ANOVA) was used to determine significant differences among formulations in terms of color/appearance, odor/aroma, taste/flavor, chewiness, and general acceptability. Return on Expenses (ROX) analysis was conducted by computing total production cost, unit cost, selling price, total sales, income, and percentage return to evaluate the economic viability of each formulation.

2.8 Ethical Considerations

The study adhered to the ethical standards set by the Isabela State University Institutional Research Ethics Board (IREB). Participants were informed about the purpose, procedures, and potential risks of the study, and participation was voluntary with the option to withdraw at any time. Informed consent was obtained, and confidentiality and anonymity were maintained. Food preparation followed proper hygiene and safety standards to ensure participant well-being. The researcher declared no conflicts of interest and used AI tools only for language enhancement while maintaining originality and proper attribution of all data and interpretations.

3. Results and Discussion

3.1 Nutritional and Sensory Evaluation of the Developed Product

3.1.1 Proximate Nutritional Composition of the Formulations

The proximate analysis showed that increasing papaya content from F1 to F4 resulted in a decrease in moisture content from 40.09% to 25.37%, while ash content slightly increased from 4.00% to 4.70%. Lipid content remained constant at 2.00% across all formulations. Protein content was stable at 4.00% for F1 to F3 but slightly increased to 4.33% in F4. Fiber content increased from 6.00% to 7.00%, carbohydrates rose from 44.00% to 56.67%, and metabolized energy increased from 6.30 kcal to 7.86 kcal, with F4 showing the highest nutritional values. The results indicate that higher papaya content improves the nutritional quality of the product by increasing fiber, carbohydrates, and energy while reducing moisture, which enhances shelf stability. The stability in lipid and protein content suggests that formulation changes primarily influenced carbohydrate and fiber levels. Lower moisture content supports preservation by limiting microbial growth, reinforcing the importance of dehydration in extending shelf life (Rasul, 2022).

3.1.2 Acceptability in Terms of Color/Appearance

The results showed that F2 obtained the highest mean score of 7.21, followed closely by F1 and F3, all interpreted as "Like Moderately," while the control (F0) received the lowest score of 4.89, interpreted as "Neither Like nor Dislike." F4 had a slightly lower score of 6.53 but remained acceptable. The overall grand mean of 6.58 indicates general acceptability of all formulations. Statistical analysis showed a significant difference among formulations (F-value = 46.44; P-value = 0.000). These findings suggest that the incorporation of papaya and Rice-Based Sagip Nutri-Powder significantly improved the visual appeal of the product compared to the control. Appearance plays a crucial role in consumer acceptance, as food color influences perception, expectations, and emotional responses (Silva et al., 2025). The high rating of F2 supports the idea that visual cues strongly affect consumer decision-making and product acceptance (Su & Wang, 2024).

3.1.3 Acceptability in Terms of Odor/Aroma

The findings revealed that F2 achieved the highest odor/aroma score of 7.12, while F1 and F3 also received moderate ratings, and F4 had a lower score of 6.33. The control (F0) had the lowest score of 5.01. The overall grand mean of 6.38 indicates that the formulations were generally acceptable but less preferred compared to other attributes. Statistical analysis confirmed significant differences (F-value = 38.52; P-value = 0.000). This indicates that the addition of papaya and Rice-Based Sagip Nutri-Powder enhanced the aroma profile of the product. Odor plays a critical role in influencing consumer preference and purchase decisions, as aroma compounds directly affect sensory perception (Liu et al., 2025). The superior performance of F2 suggests that its formulation achieved a more balanced and desirable aroma profile.

3.1.4 Acceptability in Terms of Taste/Flavor

The results showed that F1 had the highest mean score of 6.80, followed closely by F2 and F3, while F4 had a slightly lower score of 6.29. The control (F0) had the lowest score of 4.56. The overall grand mean of 6.18 indicates that the formulations were generally acceptable in taste but only moderately preferred. Significant differences were observed (F-value = 33.21; P-value = 0.000). These findings suggest that fortification improved flavor acceptability, although excessive papaya content may have slightly reduced preference due to flavor intensity changes. Taste is a primary determinant of consumer acceptance, and even nutritionally beneficial foods may be rejected if flavor is not appealing (Chen, Liu, & Feng, 2023). The results highlight the importance of balancing ingredients to maintain palatable flavor.

3.1.5 Acceptability in Terms of Chewiness

The findings indicated that F2 obtained the highest chewiness score of 6.67, followed by F1 and F3, while F4 had a slightly lower score of 6.49. The control (F0) had the lowest score of 4.59. The grand mean of 6.20 suggests overall acceptability. Statistical results showed significant differences among formulations (F-value = 47.45; P-value = 0.000). This implies that moderate papaya levels combined with fortification produced a desirable texture, while excessive papaya slightly altered chewiness. Texture is a key factor influencing food preference, and undesirable texture can reduce consumer acceptance (Choi, 2025; Guiné, 2022; IJAEB, 2023). The results confirm that optimal formulation enhances both nutritional and sensory quality.

3.1.6 General Acceptability of the Formulations

The results showed that F2 achieved the highest mean score of 7.60, followed closely by F4 (7.59), while F3 and F1 had moderate scores, and the control (F0) had the lowest score of 5.03. The overall grand mean of 6.27 indicates that the product was generally well accepted. Statistical analysis revealed highly significant differences (F-value = 946.75; P-value = 0.000). These findings indicate that F2 provided the best balance of sensory attributes, making it the most preferred formulation. Overall acceptability is influenced by combined sensory characteristics such as flavor, texture, aroma, and appearance, which determine consumer preference and purchase intention (Huey et al., 2024).

3.2 Consumer Preference and Product Ranking

3.2.1 Acceptability Consumers Index (ACI) and Most Preferred Formulation

The Acceptability Consumers Index (ACI) showed that F2 obtained the highest score of 6.89, followed by F1, F3, and F4, while F0 had the lowest score of 3.73. This indicates that F2 was the most preferred formulation based on combined sensory attributes. The results confirm that F2 achieved the most balanced combination of color, aroma, texture, and flavor, making it the optimal formulation. Composite indices such as ACI provide a comprehensive measure of consumer preference by integrating multiple sensory attributes, which is essential in food product development (Stone & Sidel, 2004).

3.3 Shelf-Life Stability of the Developed Product

The results showed that all formulations remained acceptable throughout seven days of storage. F2 maintained the highest stability, retaining its color, aroma, taste, and texture. F1 also performed well with minimal changes, while F0 showed moderate stability. In contrast, F3 and F4 exhibited faster changes, including stronger aroma, increased sourness, and texture alterations. These findings indicate that dehydration effectively preserved the product by reducing moisture content, which helps inhibit microbial growth and extend shelf life. Proper drying enhances product stability and maintains nutritional quality over time (Rasul, 2022). The superior performance of F2 highlights the importance of optimal formulation in maintaining product quality during storage.

3.4 Cost and Economic Viability Analysis

The results showed that total production cost increased from ₱47.08 in F0 to ₱57.38 in F4 due to higher papaya content, while operating costs remained constant. Unit cost increased from ₱11.77 to ₱14.35, while selling price and total sales remained constant. Income decreased from ₱24.92 to ₱14.62, and ROX declined from 52.93% to 25.48%, indicating reduced profitability as formulation cost increased. These findings suggest a trade-off between nutritional improvement and economic efficiency. While higher papaya content enhances nutritional value, it also increases production costs and reduces profit margins. The results indicate that F0 and F1 are more economically viable, while F2 offers a balance between acceptability and profitability, making it a practical option for commercialization.

4. Conclusion & Recommendations

The study concludes that the development of Ready-to-Eat Dehydrated Spicy Papaya (Carica papaya) Pickle is a feasible approach to enhancing the nutritional value of underutilized papaya while promoting food waste reduction. Increasing papaya content improved the product's nutritional profile, particularly in fiber, carbohydrates, energy, and mineral content, while reducing moisture levels that support better shelf stability. In terms of sensory acceptability, all fortified formulations were generally preferred over the control, with F2 identified as the most acceptable due to its balanced attributes in appearance, aroma, taste, texture, and overall acceptability. Shelf-life evaluation showed that all formulations remained acceptable for up to seven days, with F2 demonstrating the most stable quality. However, economic analysis revealed that higher papaya content increased production costs and reduced profitability, making F0 and F1 more cost-effective. Overall, F2 provides the optimal balance between nutritional quality, sensory acceptability, shelf stability, and economic viability, making it the most suitable formulation for potential commercialization.

Based on the findings, it is recommended to conduct a more comprehensive shelf-life assessment to evaluate storage stability under varying conditions to ensure long-term product quality and safety. Further enhancement of the product may be achieved through additional fortification using functional ingredients or natural preservatives to improve nutritional value and microbial stability without affecting sensory quality. Expanding consumer evaluation by involving a larger and more diverse group of respondents is also suggested to validate acceptability across different market segments. While F2 was identified as the most preferred formulation, minor adjustments in flavor, such as sweetness, spiciness, or seasoning, may be considered to further improve palatability. Providing clear nutritional information on packaging may also help attract health-conscious consumers. Additionally, the product may be promoted as a convenient, ready-to-eat, and nutritious food suitable for all age groups. Future studies may explore alternative fruits or vegetable combinations with Sagip Nutri-Powder to diversify product offerings and broaden consumer appeal.

The study is limited to a seven-day shelf-life observation period, which may not fully capture the long-term stability and quality changes of the product under different storage conditions. The sensory evaluation was conducted using a limited number of respondents, which may not fully represent broader consumer preferences. Additionally, the economic analysis was based on specific ingredient costs and conditions at the time of the study, which may vary in different market settings.

Compliance with ethical standards

This study adhered to the ethical standards established by the Isabela State University Institutional Research Ethics Board (IREB). The authors ensured that all participants were informed about the purpose, procedures, and potential risks of the study, and that participation was voluntary with the option to withdraw at any time. Informed consent was obtained from all participants, and confidentiality and anonymity were maintained throughout the research process. Food preparation followed appropriate hygiene and safety standards to ensure participant well-being. The authors declare no conflicts of interest and used AI tools solely for language enhancement while ensuring that all data, ideas, and interpretations remained original and properly attributed.

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