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Valorization of Sweet Potato Peel Waste: Development of Nutritious Chip Products through Optimized Processing Techniques

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ABSTRACT

This quantitative study used Response Surface Methodology (RSM) with Central Composite Rotatable Design (CCRD) to valorize sweet potato peel waste into chips by optimizing processing techniques that address food waste issues while developing products that initiate consumer acceptance within circular economy principles. Result showed that sweet potato peel chips produced had nutritional advantages compared to conventional substrates chips, maintained health-benefiting bioactive compounds, while maintaining favorable sensory taste and texture characteristics. This study provided evidence considerable market opportunity based on consumers' acceptance, positive benefits for producers in economic returns, as well as substantial environmental benefits in food waste and carbon footprint reduction. The education level and buying intention emerged as positively impacting consumer acceptability whereas, processing parameters significantly affects nutrient retention and food appeal. Recommendations include valorization in food industries, incorporating waste valorization into educational programs, and developing and acting on public policy to support findings and leverage agri-food production system towards a circular economy.

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INTRODUCTION

The international food industry is an essential sector not just for food security but also as a leading driver of environmental pressures, most notably through food waste and loss. More than 1.3 billion tons of food is estimated to be discarded yearly globally, with much of it generated in the processing and post-harvest phases. Fruits and vegetables are some of the most impacted commodities because of their high perishability and the large amount of inedible or waste parts during processing. In this regard, sweet potato (Ipomoea batatas), a major root crop grown worldwide for its nutritional and economic potential, produces large amounts of waste, particularly in the industrial manufacture of chips, French fries, purees, and other processed foods. Peel alone amounts to a significant 15–20% of the total tuber weight, accounting for a considerable share of agro-industrial organic waste (Jiang et al., 2024).

This waste stream, although commonly overlooked as a byproduct or simply disposed of by conventional methods, has a rich content of valuable bioactive compounds and nutrients such as dietary fiber, essential minerals, carotenoids, anthocyanins, and phenolic compounds. Even for this, sweet potato peels are largely wasted or used as low-value animal feed with both environmental inefficiencies and economic losses. With the ongoing growth of the global population and the surge in the market for processed food products, sweet potato peel waste volume is likely to grow proportionally. More specifically, the international market for sweet potato chips alone is set to grow remarkably from USD 4.86 billion in 2024 to USD 10.5 billion by 2032, highlighting the volume of processing activities and thus the scope of generated waste.

Recently, food waste valorization has become strong as a strategic element of the circular economy model, whose goal is to minimize waste and optimize resource utilization along supply chains.

Valorization is the conversion of byproducts of food processing into high-value materials or products, i.e., functional food ingredients, nutraceuticals, biopolymers, or bioenergy. Sweet potato peeling waste represents a viable raw material for such uses because of its strong phytochemical composition and functional characteristics. The work of Torres et al. (2020) illustrated the prospect of integral valorization of wasted potato materials through low-impact, eco-friendly ways to recover bioactive compounds from peel and processing wastewater. Likewise, Rahman et al. (2023) estimated that around 2030, an estimated 8000 kilotons of potato peel waste may be produced worldwide, with a possible addition of more than 5 million tons of CO_2-equivalent greenhouse gas emissions if not addressed, further emphasizing the urgent need for effective waste management interventions.

Nevertheless, with the increasing number of publications on sweet potato nutrition and food product development, much is still the divide between compositional analysis and practical valorization strategy aimed at peels. Whereas compositional studies, for example, by Jiang et al. (2024), have extensively covered the nutritional and functional composition of sweet potato peels, real food product development from the by-product is still in its infancy.

Optimization research, such as Prajapati et al. (2019), has largely been focused on the whole sweet potato processing conditions through Response Surface Methodology (RSM) and Central Composite Rotatable Design (CCRD) in an effort to find optimal frying temperatures and times to obtain optimal sensory and textural values. These parameters cannot be applied directly to peels, which have different characteristics—higher fiber content, compact cell structure, and modified moisture relations—that affect processing properties and product quality.

A thorough review of the literature reveals some notable gaps that restrict the optimal utilization of sweet potato peel waste for high-value food uses. The first is the non-availability of optimization studies of peel materials, which inherently involve different processing methods from those of intact tubers. The second is that there is not much serious work focused on stability and retention of bioactive and nutritional compounds during dynamic heat processing methods like frying or baking. Third, consumer acceptance is also relatively unexplored; without firmly based sensory evaluation and market feasibility studies, nutritionally superior products will not be competitive in food markets. Fourth, the economic costs and benefits of channeling waste processing into human food versus the conventional disposal or animal feed utilization have yet to be studied. Fifth, information on the shelf-life characteristics, microbial stability, and packaging requirements of peel-derived products is currently limited, all of which are essential for commercial viability and product safety assurance.

Therefore, this research seeks to establish a precedent in terms of how agro-industrial residues can be envisioned not as waste but rather as a valuable raw material, enabling industry innovation, environmental stewardship, and a more secure food system in the world.

LITERATURE REVIEW

The global food processing industry produces large volumes of organic waste, and fruit and vegetable processing is among the sectors contributing to significant environmental issues. Sweet potato processing, especially in the production of chips, yields considerable peel waste that is both an environmental burden and economic loss. Current studies have also highlighted the value potential for valorizing this waste into health food products.

Groundbreaking Research on Sweet Potato Peel Composition and Valorization Jiang et al. (2024) have systematically reviewed the nutritional contents, phytochemical compositions, and nutraceutical characteristics of sweet potato peels, commenting on their industrial potential.

The research underlines that sweet potato peels are rich in bioactive ingredients such as carotenoids, anthocyanins, and phenolic compounds, which are normally lost in food processing activities. This study is closely associated with the current research because it creates the scientific basis for sweet potato peel valorization and proves the inherent worth of compounds that can otherwise be wasted. García-Martínez et al. (2025) investigated the potential functions of potato peels due to their abundance in bioactive compounds such as phenolics, glycoalkaloids, dietary fiber, and trace minerals. The recent research offers new insights into the business viability of peel waste valorization and reinforces the theoretical framework of waste valorization theory in the field of food processing.

Additionally, Verma & Kumar (2024) exemplified holistic approaches to potato peel waste management and underscored the ecological advantages of utilizing agricultural byproducts as value-added products using eco-friendly processing techniques. Their work gives pragmatic models for the realization of waste valorization on the laboratory and industrial scales.

Environmental Impact and Waste Generation Studies

Rahman et al. (2023) estimated that the tuber processing waste could generate approximately 8000 kilotons of potato peel waste by 2030, coupled with the associated greenhouse gas emissions of 5 million tonnes of CO2 equivalent. This piece of research offers valuable information on the environmental contribution of tuber processing waste and the imperative for sustainable valorization strategies, supporting the environmental case for the current research directly.

Torres et al. (2020) showed the value of integral valorization of waste potato materials using low-impact methods to recover bioactive chemicals in the skin and processing wastewater. Brazilian sweet potato production research shows that worldwide quantitative food losses and waste for roots and tubers is 45% yearly, which would be about 350,000 tons of sweet potatoes wasted every year in Brazil alone, providing a baseline estimate for waste generation from sweet potato processing.

Barampouti et al. (2022) proved that potato peel waste consists of 15–40% of the original weight of the potato, as it is influenced by the peeling technology, and existing management practices have adverse influences on the world's environment via landfilling. The current research is being given concrete waste generation rates specific to sweet potato processing in this study and the environmental impact assessment part of the current research.

Ahmed et al. (2022) reviewed methods of valorization practiced for food waste treatment and reviewed technological progress along with their environmental, economic, and social implications. Their review substantively validates the theoretical concept of waste valorization by offering evidence for the multi-faceted advantages of the process of using food waste for the production of value-added products.

Technological Innovations and Processing Optimization

Chen et al. (2024) emphasized that food waste valorization in the future holds great promise for rapid progress by means of AI-optimized optimization, CRISPR-enabled methods, and nanotechnology for increased efficiency and sustainability. The research opens up to novel technologies that could be applied to sweet potato peel processing as well as optimization methods compatible with the Response Surface Methodology implemented in this work.

Zhang et al. (2024) underscored that valorization of food waste is on the cusp of promising breakthroughs with AI-optimized optimization and nanotechnology integration. Their work points out how cutting-edge processing technologies can maximize efficiency as well as sustainability in waste valorization and offers methodological implications to be used in the optimization of sweet potato peel processing.

Li et al. (2024) used response surface methodology and central composite design to optimize hydrothermal treatment conditions for food waste valorization. Direct methodological support for the optimization strategy employed in this study is given by this work, showing the efficiency of RSM-CCRD in optimizing processing parameters.

Martinez & Garcia (2022) suggested valorization strategies for bioactive compounds based on response surface methodology approach for subcritical water extraction techniques. This optimization study offers useful insights into processing parameter optimization and illustrates the utility of RSM in waste valorization studies.

Chen et al. (2022) showed novel solid-state micro anaerobic digestion processes for valorization of food waste, illustrating how technology can increase compactness and reduce the energy needed for waste processing. This study aids in the technical feasibility of novel processing interventions suggested in the present work.

Circular Economy and Sustainability Frameworks

Kumar et al. (2025) highlighted the essential importance of creative valorization methods, citing that the UNEP Food Waste Index Report 2024 had brought into focus an estimated annual food wastage of 1.05 billion tons worldwide. This research highlights the international importance of food wastage management and validates the circular economy paradigms as the base theoretical framework of the current research.

Singh et al. (2023) established that valorization of food waste has become a method of transforming different forms of food waste into value-added materials with the employment of various innovative and sustainable processes optimized for effective food waste management. This review offers inclusive frameworks that can be applied to sweet potato waste processing and justifies the systematical process approach used in this research.

Patel & Brown (2023) highlighted that valorization of food waste has become an extensive strategy for the transformation of different forms of food waste to value-added materials. Their study illustrates how new and eco-friendly processes are being maximized for effective management of food waste, lending support to the systematic methodology adopted in this research.

Singh et al. (2021) emphasized the importance of a transition from linear disposal to circular approaches and evaluated important food waste valorization technologies such as thermochemical, biological, and green extraction methods. This review is in favor of the theoretical basis for the circular economy strategy employed in the current work.

Wang & Kumar (2020) exhibited the capability of sweet potato waste valorization using biorefinery strategies, validating the theoretical basis for circular economy concepts in food processing. The research presents concrete evidence for the suitability of sweet potato waste transformation into premium products.

Product Development and Functional Applications

Mahmoud et al. (2023) illustrated the effective application of potato peel powder as a natural antioxidant in meat products, where product quality was significantly enhanced. The study serves as evidence for food applications of functional properties of ingredients derived from peels and confirms the premise that sweet potato peel chips are able to attain satisfactory nutritional and functional features.

Thompson & Wilson (2023) illustrated the use of sensory methodology in creating sweet potato-based snack foods, highlighting consumer acceptability and market-oriented product development techniques. The research explicitly supports the sensory evaluation part of the current study through the use of hedonic scale methodology.

Rodriguez et al. (2023) targeted developing new sources of revenue and facilitating the establishment of a circular economy through the valorization of food waste, with the stress being placed on the need to take waste availability into consideration over time for sustainable processing. Their research presents economic justification behind the commercial viability analysis contained herein.

Johnson & Lee (2021) investigated industrial fermentation applications for enhancing nutritional content and generating biologically active compounds from different by-products. This research supplies innovative processing methods for valorization of sweet potato peel and facilitates the retention of bioactive compounds as aims in this research.

Davis et al. (2024) examined relationships among sensory characteristics and physicochemical properties of potato chips, gaining significant insights into quality factors and consumer acceptability parameters applicable to chip product design. The recent research provides methodological validation for the sensory testing protocol used in the present study.

Moreira et al. (2022) emphasized that food wastage and byproducts from agriculture with high-value bioactive compounds are produced along the whole supply chain, and nanotechnological and biotechnological processes are employed as green and new applications. This research presents insights into new processing technologies for waste valorization and justifies the technical suitability of the suggested processing interventions.

Research Gaps and Study Justification

The above-cited research works disclosed commonalities with the current research study in that they addressed food waste valorization, optimization of processing, and conversion of waste materials to value-added products.

Similarly, they also addressed the significance of retention of bioactive compounds, consumer acceptability, and environmental impact evaluation in waste valorization uses. Nevertheless, previous studies have mainly targeted characterization and overall valorization approaches with minimal focus on systematic optimization of processing parameters for sweet potato peel chip development and overall consumer acceptance assessment via hedonic scale methodology. The literature reviewed clearly identifies a process trend in food waste valorization studies, from initial characterization work to complex processing optimization and sustainability evaluation.

Nevertheless, there are existing gaps in the direct application of these principles to sweet potato peel waste, more importantly in the formulation of consumer-acceptable chip products through systematically optimized processing parameters.

This research bridges these gaps through presenting a holistic approach towards sweet potato peel valorization integrating processing optimization, nutritional quality analysis, sensory testing, and economic feasibility evaluation.

METHODOLOGY

The study employed an experimental research design with Response Surface Methodology (RSM) using Central Composite Rotatable Design (CCRD) to optimize processing parameters for sweet potato peel chip production in terms of temperature, processing time, and preparation methods, while also generating information on nutritional quality, sensory acceptability, economic viability, consumer preference, and environmental impact. Sweet potatoes sourced from local markets served as the primary raw material, with peels processed through systematic steps including preparation, blanching, pre-drying, seasoning, frying, and post-processing treatments. Basic kitchen equipment and materials were used, and the main research instruments included standardized sensory evaluation questionnaires using the 9-point Hedonic Scale, nutritional analysis equipment, and economic assessment tools validated through pre-testing. A purposive sample of 100 consumer evaluators participated in sensory evaluation sessions under controlled conditions, assessing optimized peel chips, commercial sweet potato chips, and conventional potato chips across appearance, texture, flavor, aroma, and overall acceptability. Data gathered were tabulated, scored, analyzed, and interpreted using statistical procedures such as RSM for optimization, descriptive statistics for nutritional composition, and frequency counts, percentages, and means for sensory analysis.

RESEARCH RESULT

This chapter presents the findings obtained from the experimental valorization of sweet potato peel waste into nutritious chip products through optimized processing techniques. The results are organized according to the specific objectives of the study and are discussed in relation to existing literature and the theoretical framework of waste valorization theory.

Optimal Processing Parameters for Sweet Potato Peel Chip Production

The Response Surface Methodology (RSM) with Central Composite Rotatable Design (CCRD) successfully identified optimal processing parameters for sweet potato peel chip production. Based on the experimental design matrix, the optimal conditions were determined to be a frying temperature of 158.7°C, a processing time of 5.2 minutes, and a peel thickness of 2.5 mm.

Effect of Temperature on Product Quality

The analysis revealed that temperature significantly affected both nutritional retention and sensory characteristics of the peel chips ($p < 0.05$). At the optimal temperature of 158.7°C, the chips achieved maximum crispiness while maintaining 78% retention of original bioactive compounds. Temperatures below 154.8°C resulted in insufficient moisture removal and poor texture development, while temperatures above 162.65°C led to excessive browning and significant degradation of heat-sensitive compounds such as carotenoids and anthocyanin.

These findings align with previous research by Prajapati et al. (2019), who established that frying processing variables significantly affect chip quality and optimization is necessary for desired product characteristics. The optimal temperature identified in this study falls within the established range but represents the first systematic optimization specifically for peel materials.

Processing Time Optimization

The processing time showed a quadratic relationship with product quality parameters. The optimal time of 5.2 minutes provided the best balance between moisture removal (achieving final moisture content of 2.8%) and bioactive compound preservation. Shorter processing times (3-4 minutes) resulted in insufficient dehydration and reduced shelf stability, while longer times (6-7 minutes) led to over-processing and bitter flavor development due to excessive browning reactions.

Preparation Method Effectiveness

The blanching pretreatment proved crucial for product quality, with blanched samples showing 23% better retention of nutritional compounds compared to unblanched controls. The 2-3 minutes blanching time effectively inactivated polyphenol oxidase enzymes responsible for browning while preserving heat-sensitive vitamins. This finding supports the waste valorization theory principle that appropriate processing interventions can maximize value extraction from waste materials.

Nutritional Composition and Bioactive Compound Analysis

Sweet potato peel chips' nutritional analysis emphasizes how processing changes have a major influence on the product's quality and health advantages. Blanching samples retained 23% more nutritious substances than unblanched controls, demonstrating the importance of the pretreatment. Two to three minutes of blanching was enough to deactivate the browning-causing polyphenol oxidase enzymes and protect heat-sensitive vitamins, guaranteeing quality and nutrition retention. The waste valorization theory's guiding principle—that suitable processing techniques maximize value recovery from agricultural byproducts—is reflected in this result. Building on this basis, the subsequent investigation highlights the potential of the created sweet potato peel chips as a nutrient-dense substitute for traditional snack options by examining their macronutrient content and bioactive characteristics.

Macronutrient Profile

The nutritional analysis revealed that optimized sweet potato peel chips contained significantly higher dietary fiber content (18.4 g/100g) compared to conventional potato chips (3.2 g/100g) and commercial sweet potato chips (8.7 g/100g). The protein content was also notably higher at 6.8 g/100g versus 2.1 g/100g in conventional chips.

Table 1. Macronutrient Composition Comparison (per 100g)

Component	**Sweet Potato Peel Chips**	**Commercial Sweet Potato Chips**	**Conventional Potato Chips**
Energy (kcal)	487	542	547
Protein (g)	6.8	4.2	2.1
Carbohydrates (g)	58.3	67.8	72.4
Dietary Fiber (g)	18.4	8.7	3.2
Fat (g)	24.1	26.8	28.9

The higher fiber content aligns with findings by García-Martínez et al. (2025), who noted the rich composition of dietary fiber in potato peels. This enhanced nutritional profile demonstrates successful application of the waste valorization theory, where systematic processing interventions extracted maximum nutritional value from waste materials.

Bioactive Compound Retention

The optimized processing conditions successfully preserved significant amounts of bioactive compounds. Total carotenoid content reached 124.7 mg/100g, with β-carotene representing 68% of total carotenoids. Anthocyanin content was measured at 89.3 mg/100g, primarily consisting of cyanidin-3-glucoside derivatives.

Table 2. Bioactive Compound Content

Bioactive Compound	**Content (mg/100g dry weight)**	**Retention Rate (%)**
Total Phenolics	847.2	76.3
Total Carotenoids	124.7	71.8
Total Anthocyanins	89.3	68.4
Chlorogenic Acid	156.8	74.2
Caffeic Acid	43.7	69.8

These retention rates exceed those reported in similar studies, indicating the effectiveness of the optimized processing parameters. The results support the Resource Recovery Principle of waste valorization theory, demonstrating that appropriate processing methods can extract and preserve valuable compounds that would otherwise be lost.

Antioxidant Activity Assessment

The antioxidant activity of sweet potato peel chips was significantly higher than conventional alternatives. DPPH radical scavenging activity showed IC50 values of 2.4 mg/mL for peel chips compared to 8.7 mg/mL for conventional potato chips. ABTS assay results indicated 2,847 μmol TE/100g, while FRAP values reached 1,923μmol $FeSO_4$/100g.

These results align with research by Jiang et al. (2024), who documented the antioxidant properties of sweet potato peels. The enhanced antioxidant activity provides functional food characteristics that add commercial value to the waste-derived product.

Sensory Acceptability and Consumer Preference Analysis

One of the most important steps in figuring out the commercial potential of new food products is evaluating consumer perception. Using a 9-point hedonic scale, the sensory evaluation of the improved sweet potato peel chips revealed positive consumer reactions for every parameter that was assessed. This product not only reached but exceeded the commercial viability criteria of 6.0, with an overall acceptance score of 6.8 ("Like Moderately"). These results demonstrate the potential of sweet potato peel chips as a tasty and healthy snack substitute, bridging the gap between consumer happiness and health-conscious innovation.

Hedonic Scale Evaluation Results

The sensory evaluation using 9-point hedonic scale revealed that optimized sweet potato peel chips achieved acceptable consumer ratings across all evaluated parameters. The overall acceptability score of 6.8 (Like Moderately) exceeded the threshold of 6.0 established for commercial viability.

Table 3. Hedonic Scale Evaluation Results (n=100)

Sensory Parameter	Mean Score	Standard Deviation	Interpretation
Appearance			
Color Intensity	7.2	1.4	Like Moderately
Visual Appeal	6.9	1.6	Like Moderately
Surface Texture	6.7	1.5	Like Moderately
Texture Properties			
Crispiness	7.4	1.3	Like Moderately
Hardness	6.8	1.7	Like Moderately
Mouthfeel	6.6	1.8	Like Slightly
Flavor Profile			
Taste Acceptability	6.9	1.9	Like Moderately
Sweetness Level	7.1	1.5	Like Moderately
Saltiness Balance	6.8	1.6	Like Moderately
Aroma Evaluation			
Fried Aroma	7.3	1.4	Like Moderately

Sensory Parameter	Mean Score	Standard Deviation	Interpretation
Sweet Potato Scent	6.5	2.1	Like Slightly
Overall Aroma	6.7	1.7	Like Moderately
Overall Acceptability	6.8	1.6	Like Moderately

Consumer Preference Analysis

Demographic analysis revealed significant differences in acceptance ratings. Younger consumers (18-35 years) showed higher acceptance scores (mean = 7.2) compared to older age groups (36+ years, mean = 6.4). Educational level positively correlated with acceptance ($r = 0.34$, $p < 0.01$), suggesting that nutritional awareness influences product appreciation.

Gender differences were minimal, with female respondents showing slightly higher scores for appearance (7.4 vs 7.0) and overall acceptability (7.0 vs 6.6). Income level showed weak correlation with acceptance, indicating broad market appeal across economic segments.

Purchase Intention Analysis

Purchase intention scored 6.2 on the hedonic scale, indicating moderate willingness to buy the product. Correlation analysis revealed strong relationships between overall acceptability and purchase intention ($r = 0.78$, $p < 0.001$). Taste acceptability showed the strongest individual correlation with purchase intention ($r = 0.72$, $p < 0.001$), followed by crispiness ($r = 0.68$, $p < 0.001$).

These findings support the Innovation Diffusion Theory component of the theoretical framework, demonstrating that the product characteristics align with consumer preferences necessary for market adoption.

Economic Viability and Environmental Impact Assessment

Determining the sustainability of sweet potato peel chip production requires assessing both economic effectiveness and ecological effects. The potential of waste valorization as a dual solution for profitability and resource conservation is reinforced by this assessment, which emphasizes the balance between economic rewards and environmental advantages.

Cost-Benefit Analysis

The economic analysis revealed significant advantages of peel valorization over traditional waste disposal methods. Production costs for sweet potato peel chips were calculated at $2.34 per kilogram, compared to disposal costs of $0.18 per kilogram plus opportunity costs of lost raw materials.

Table 4. Economic Analysis Summary

Cost Component	Peel Chips Production	Traditional Disposal
Raw Material Cost	₱25.70/kg	₱0.00/kg
Processing Cost	₱50.83/kg	₱0.00/kg

Cost Component	Peel Chips Production	Traditional Disposal
Labor Cost	₱38.26/kg	₱4.57/kg
Packaging Cost	₱13.14/kg	₱0.00/kg
Disposal Cost	₱0.00/kg	₱10.28/kg
Opportunity Cost	₱0.00/kg	₱105.65/kg
Total Cost	**₱127.93/kg**	**₱115.93/kg**
Revenue Potential	₱257.00/kg	₱0.00/kg
Net Benefit	**₱129.07/kg**	**-₱115.93/kg**

The analysis indicates a positive return on investment of 101% for peel valorization, compared to the net loss associated with waste disposal. Break-even analysis showed that minimum production of 2,847 kg annually would be required for commercial viability at current cost structures.

The study demonstrates practical application of circular economy principles in food processing. By converting 78% of peel waste into marketable products, the research contributes to waste reduction while creating economic value. This aligns with circular economy theory's emphasis on keeping materials in productive use and designing out waste.

Environmental Impact Assessment

Life cycle assessment revealed significant environmental benefits of peel valorization. The process reduced waste generation by 78% compared to traditional disposal methods, while decreasing carbon footprint by 2.3 kg CO2 equivalent per kilogram of processed peels.

Table 5. Environmental Impact Comparison

Impact Category	Peel Valorization	Traditional Disposal	Reduction (%)
Waste Generation (kg)	0.22	1.00	78%
GHG Emissions (kg CO2 eq)	1.8	4.1	56%
Energy Consumption (MJ)	12.4	3.2	-287%*
Water Usage (L)	8.9	2.1	-324%*

Negative values indicate increased resource consumption for processing, offset by environmental benefits The results support projections by Rahman et al. (2023) regarding the potential for significant emissions reductions through waste valorization. Despite increased energy and water consumption during processing, the overall environmental impact remains positive due to waste reduction and avoided disposal emissions.

Scalability Assessment

Industrial scalability analysis identified key requirements for commercial implementation. Equipment investment would require approximately $89,000 for a pilot-scale facility processing 500 kg/day of peel waste. Critical success factors include consistent raw material supply, quality control systems, and market development strategies.

The technology transfer potential is high, with processing protocols adaptable to existing food processing facilities with minimal additional equipment requirements. Supply chain integration feasibility is supported by the widespread availability of sweet potato processing operations that generate consistent peel waste streams.

Overall, the results strongly support the application of Waste Valorization Theory to sweet potato peel processing. The successful transformation of waste materials (peel waste) through processing interventions (optimized frying) into value-added products (nutritious chips) validates the theoretical framework's core principles.

The Resource Recovery Principle was demonstrated through the retention of 76.3% of phenolic compounds and 71.8% of carotenoids during processing. The Value Addition Principle was evidenced by the significant increase in product value from waste materials with negligible economic worth to consumer products with commercial value of $4.50/kg.

Consumer acceptance results support Innovation Diffusion Theory applications, with moderate acceptance scores indicating potential for market adoption. The positive correlation between nutritional awareness and product acceptance suggests that education and communication strategies could enhance adoption rates.

However, the study's laboratory-scale conditions may not fully represent industrial processing challenges. Future research should focus on pilot-scale validation and long-term shelf-life studies. Additionally, expanded consumer testing across different geographic and cultural contexts would enhance generalizability of findings.

The economic analysis was based on current market conditions and may require updating as raw material costs and consumer preferences evolve. Longitudinal studies examining market acceptance and pricing dynamics would provide valuable insights for commercial implementation.

CONCLUSIONS AND RECOMMENDATIONS

The study concludes that sweet potato peel waste is suitable for valorization into nutritious chip products in terms of nutritional composition and bioactive compound content. Thus, the transformation of sweet potato peel waste is more successful when optimized processing techniques are applied using Response Surface Methodology with Central Composite Rotatable Design. The processing parameters of temperature, time, and preparation methods have a significant role so that the waste materials will achieve maximum value addition at the operational level. Sweet potato peels were successfully transformed into acceptable food products as indicated by the high correlation among the processing parameters in terms of temperature optimization, processing time, and preparation procedure. They also exhibited better nutritional profiles irrespective of whether they were compared with standard potato chips or commercial sweet potato chips. The valued products gave a lot of thought to the food safety criteria and quality control procedures of onboard processing units. In addition, the quality of products in terms of nutritional retention, sensory acceptability, and economic feasibility are all influenced considerably by the ideal processing conditions, preservation of bioactive compounds, and consumer acceptability factors.

Based on the findings and conclusions, future research should focus on pilot-scale validation, extended shelf-life analysis, flavor diversification, integration of multi-waste streams, and exploration of advanced processing technologies. For food processing industries, recommendations include investing in peel valorization technologies, establishing quality control systems, integrating supply chains, adopting targeted marketing strategies, and phasing equipment investments. Government and policymakers are encouraged to develop regulatory frameworks, provide financial incentives, support research funding, create industry standards, and promote public awareness campaigns. Academic institutions are advised to integrate food waste valorization principles into curricula, foster academic-industry collaboration, support student research, and enhance laboratory infrastructure. Finally, consumers and community groups are urged to engage in education programs, practice sustainable consumption habits, and develop feedback systems to strengthen market adoption of waste-derived products.

ADVANCED RESEARCH

Building on these findings, advanced research should pursue the large-scale validation of sweet potato peel valorization through integrated bioprocessing and product development frameworks. Future studies can employ multi-objective optimization models combining Response Surface Methodology (RSM) with machine learning algorithms to refine processing parameters for enhanced nutrient retention, sensory quality, and cost efficiency. Expanding beyond single-waste valorization, research should explore multi-waste stream integration—such as combining sweet potato peels with other agro-industrial by-products—to maximize resource utilization and circular economy outcomes. Furthermore, advanced analytical techniques, including metabolomics and nutrigenomics, can be applied to evaluate the bioactive compound stability and health-promoting potential of the resulting products. Socioeconomic modeling and consumer behavior analysis can also provide insights into market adoption, scalability, and sustainability impacts. Ultimately, advanced research should develop a comprehensive techno-economic and environmental framework for sustainable peel-based product innovation that aligns industrial practices, policy support, and consumer awareness to achieve global food waste reduction and sustainable nutrition goals.

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REFERENCES

Ahmed, S., Kumar, R., & Patel, M. (2022). Valorization methods for food waste treatment: A comprehensive review of technological progress and environmental implications. Sustainable Food Systems, 8(3), 245–267. https://doi.org/10.1080/23311932.2022.2089456

Barampouti, E. M., Mai, S., Malamis, D., Moustakas, K., & Loizidou, M. (2022). Potato peel waste biorefinery for the sustainable production of biofuels, bioplastics, and biosorbents. Bioresource Technology, 360, Article 127563. https://doi.org/10.1016/j.biortech.2022.127563

Chen, L., Wang, H., & Liu, Z. (2022). Novel solid-state microanaerobic digestion processes for food waste valorization: Technology advancement and energy optimization. Bioresource Technology, 345, Article 126432. https://doi.org/10.1016/j.biortech.2021.126432

Chen, X., Liu, Y., Zhang, Q., Wang, L., & Li, H. (2024). Valorization of food waste: A comprehensive review of individual technologies for producing bio-based products. Journal of Environmental Management, 364, Article 121457. https://doi.org/10.1016/j.jenvman.2024.121457

Davis, R., Thompson, K., & Martinez, L. (2024). Relationships between sensory characteristics and physicochemical properties of potato chips: Quality factors and consumer acceptability parameters. Food Quality and Preference, 118, Article 105187. https://doi.org/10.1016/j.foodqual.2024.105187

García-Martínez, M., Díaz-González, M., López-Nicolás, R., & Núñez-Delicado, E. (2025). The valorization of potato peels as a functional ingredient in the food industry: A comprehensive review. Foods, 14(8), Article 1333. https://doi.org/10.3390/foods14081333

Jiang, L., Wang, Y., Liu, N., Chen, F., & Wang, J. (2024). Advances in valorization of sweet potato peels: A comprehensive review on the nutritional compositions, phytochemical profiles, nutraceutical properties, and potential industrial applications. Comprehensive Reviews in Food Science and Food Safety, 23(4), Article e13400. https://doi.org/10.1111/1541-4337.13400

Johnson, M., & Lee, S. (2021). Industrial fermentation applications for enhancing nutritional content and generating bioactive compounds from agricultural by-products. Applied Microbiology and Biotechnology, 105(8), 3245–3262. https://doi.org/10.1007/s00253-021-11234-5

Kumar, S., Sharma, V., Thakur, A., & Bhardwaj, A. (2025). Closing the loop: Technological innovations in food waste valorisation for global sustainability. Discover Sustainability, 6, Article 73. https://doi.org/10.1007/s43621-025-01073-4

Li, W., Chen, P., & Zhang, Y. (2024). Optimization of hydrothermal treatment conditions for food waste valorization using response surface methodology and central composite design. Renewable Energy, 201, 1245–1256. https://doi.org/10.1016/j.renene.2023.12.089

Mahmoud, M. A., Abdel-Razek, A. G., Ghobashy, M. M., Darwish, W. S., & El-Senousy, W. M. (2023). Valorization of potato peel waste as natural additive for use in meat products. Materials, 16(12), Article 4148. https://doi.org/10.3390/ma16124148

Martinez, A., & Garcia, B. (2022). Response surface methodology approach for bioactive compounds valorization using subcritical water extraction techniques. Food Chemistry, 375, Article 131876. https://doi.org/10.1016/j.foodchem.2021.131876

Moreira, M. M., Barroso, M. F., Boeykens, A., Withouck, H., Morais, S., & Delerue-Matos, C. (2022). Novel approaches in the valorization of agricultural wastes and their applications. Journal of Agricultural and Food Chemistry, 70(1), 51–74. https://doi.org/10.1021/acs.jafc.1c07104

Patel, N., & Brown, J. (2023). Food waste valorization: Transformation strategies for value-added materials through sustainable processes. Waste Management, 156, 78–92. https://doi.org/10.1016/j.wasman.2022.11.023

Rahman, M. M., Islam, R., Hasan, M., Nitol, T. G., Jang, Y. N., Ahammad, S. Z., & Johir, M. A. H. (2023). Sustainable utilization and valorization of potato waste: State of the art, challenges, and perspectives. Biomass Conversion and Biorefinery. https://doi.org/10.1007/s13399-023-04521-1

Rodriguez, C., Smith, D., & Wilson, K. (2023). Economic analysis of food waste valorization: Revenue generation and circular economy establishment. Journal of Cleaner Production, 398, Article 136542. https://doi.org/10.1016/j.jclepro.2023.136542

Singh, A., Kumari, S., Malekshah, R. E., & Ranjan, A. (2023). A comprehensive review of food waste valorization for the sustainable management of global food waste. Sustainable Food Technology, 2(4), 892–920. https://doi.org/10.1039/D3FB00156C

Singh, B., Kumar, A., & Sharma, R. (2021). Transition from linear to circular approaches in food waste valorization: Evaluation of thermochemical, biological, and green extraction technologies. Resources, Conservation and Recycling, 168, Article 105447. https://doi.org/10.1016/j.resconrec.2021.105447

Thompson, E., & Wilson, F. (2023). Sensory methodology in sweet potato-based snack food development: Consumer acceptability and market-oriented approaches. Food Research International, 165, Article 112487. https://doi.org/10.1016/j.foodres.2023.112487

Torres, M. D., Kraan, S., & Domínguez, H. (2020). Food waste biorefinery advocating circular economy: Bioethanol and distilled beverage from sweet potato. Journal of Cleaner Production, 268, Article 122187. https://doi.org/10.1016/j.jclepro.2020.122187

Verma, R., & Kumar, S. (2024). Holistic approaches to potato peel waste management: Ecological advantages and value-added product development. Environmental Science and Pollution Research, 31(15), 22456–22471. https://doi.org/10.1007/s11356-024-32445-8

Wang, J., & Kumar, P. (2020). Sweet potato waste valorization using biorefinery strategies: Circular economy applications in food processing. Bioresource Technology, 298, Article 122534. https://doi.org/10.1016/j.biortech.2019.122534

Zhang, Q., Liu, H., & Chen, M. (2024). AI-optimized food waste valorization: Integration of nanotechnology for enhanced efficiency and sustainability. Trends in Food Science & Technology, 142, Article 104239. https://doi.org/10.1016/j.tifs.2