

Original Research Article

Waste Valorization of Tofu Residue through Zero-Waste Snack Development: A Business Feasibility Assessment

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ABSTRACT

Agro-industrial by-products represent an important resource for advancing circular economy practices through waste valorization and sustainable food production. Among these by-products, tofu residue (okara) remains underutilized despite its nutritional value and potential for conversion into value-added food products. This study aimed to develop a zero-waste snack product using tofu residue and to evaluate its business feasibility as a sustainable waste valorization strategy. A prototype-based product development approach was implemented through three production cycles conducted in Meureubo Subdistrict, West Aceh Regency, Indonesia. The business feasibility assessment employed Cost of Goods Sold (COGS), Break-Even Point (BEP), Revenue–Cost (R/C) Ratio, and Return on Investment (ROI) analyses. Six product prototypes were successfully developed, with a total production cost of IDR 194,000 for 100 packages, resulting in a COGS of IDR 1,940 per package. Financial analysis yielded an R/C Ratio of 2.58, an ROI of 157.73%, a profit of IDR 306,000 per production cycle, and a break-even point of 39 packages, indicating strong economic feasibility. These findings demonstrate that transforming tofu residue into a marketable snack can support waste valorization, promote resource efficiency, and contribute to sustainable entrepreneurship within a circular food system. The study provides practical evidence that zero-waste product innovation can simultaneously generate economic value while reducing agro-industrial waste.

keywords: *tofu pulp; entrepreneurship; food sustainability; added value; zero waste; business feasibility*

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INTRODUCTION

The increasing generation of agro-industrial food waste has become a significant global sustainability challenge, particularly in developing countries where waste management infrastructure remains limited. In Indonesia, the tofu processing industry is a widespread sector in various regions because it is a low-cost source of vegetable protein that is widely consumed by the public (Central Statistics Agency, 2024). High tofu consumption leads to daily production in large quantities, which also generates significant volumes of waste. In response, the transition from the traditional linear economy toward a circular economy has encouraged the adoption of waste valorization strategies that transform agricultural and food-processing by-products into value-added products (Geissdoerfer et al., 2017; Kirchherr et al., 2017). Within the food sector, circular food systems emphasize maintaining the value of biological resources through reuse, recycling, and resource recovery while simultaneously reducing environmental impacts and supporting sustainable economic development (Jurgilevich et al., 2016; Ellen MacArthur Foundation, 2019).

Among agro-industrial by-products, tofu residue (okara) represents one of the most abundant yet underutilized food-processing residues. Tofu production generates substantial quantities of wet residue that retain considerable amounts of protein, dietary fiber, carbohydrates, lipids, and essential minerals (Colletti et al., 2020; Rahmawati et al., 2020; Li et al., 2012). Despite its high nutritional value, okara is commonly used as low-value animal feed or discarded as organic waste. Such practices not only limit its economic potential but may also contribute to environmental problems, including odor generation and water pollution, when disposal is inadequately managed (Arta et al., 2026; Colletti et al., 2020; Vong & Liu, 2016).

The zero-waste concept encourages the utilization of production waste materials into new products with added value (Muzdalifah & Ruqayyah, 2025) and is suitable for the consumption patterns of today's young generation, who increasingly prefer unique, healthy, and environmentally friendly snack products, opening up promising business opportunities (Bastomi et al., 2024). Previous studies have demonstrated the potential of tofu residue as a raw material for various food products, including crackers, cookies, flour, noodles, bakery products, and high-fiber functional foods (Li et al., 2012; Vong & Liu, 2016; Colletti et al., 2020). These studies consistently report that okara incorporation improves nutritional quality by increasing dietary fiber and protein content while simultaneously reducing food waste. Nevertheless, the existing literature has predominantly focused on product formulation, nutritional composition, and sensory evaluation, with comparatively limited attention devoted to evaluating the commercial feasibility of waste-derived food products. Furthermore, relatively few studies explicitly position tofu residue utilization within the broader framework of the circular economy and food waste valorization, particularly in small-scale agro-industrial enterprises operating in developing countries (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

This limitation reveals an important research gap. Although tofu residue has been widely recognized as a promising food ingredient, there remains insufficient empirical evidence regarding the integration of zero-waste product innovation with business feasibility assessment as a practical waste valorization strategy. Understanding both the technical



development of innovative food products and their economic viability is essential for supporting the transition toward sustainable circular food systems and promoting sustainable entrepreneurship (Jurgilevich et al., 2016; Lüdeke-Freund et al., 2019).

To address this gap, the present study develops *RenyahLoka*, a zero-waste snack product utilizing tofu residue as its primary raw material, and evaluates its business feasibility through financial performance indicators. By combining product innovation with business feasibility assessment, the study extends previous research beyond product development alone and demonstrates the practical implementation of waste valorization principles within the context of sustainable entrepreneurship and circular food systems (Geissdoerfer et al., 2017; Lüdeke-Freund et al., 2019).

Specifically, this study aims to develop a tofu-residue-based zero-waste snack product and evaluate its business feasibility using Cost of Goods Sold (COGS), Break-Even Point (BEP), Revenue–Cost (R/C) Ratio, and Return on Investment (ROI). The findings are expected to contribute to the growing literature on circular economy, food waste valorization, and sustainable entrepreneurship while providing practical insights for small and medium-sized agro-industrial enterprises seeking to convert food-processing residues into commercially viable products.

LITERATURE REVIEW

2.1 Circular Economy and Waste Valorization

The transition from the conventional linear "take–make–dispose" production model toward a circular economy has become a fundamental strategy for addressing resource scarcity, environmental degradation, and sustainable economic development (Geissdoerfer et al., 2017; Kirchherr et al., 2017). The circular economy seeks to retain the value of products, materials, and resources for as long as possible through reuse, recycling, remanufacturing, and resource recovery, thereby minimizing waste generation and reducing dependence on virgin resources (Korhonen et al., 2018; Murray et al., 2017). Within the agri-food sector, these principles are implemented through waste valorization, which transforms underutilized agricultural and food-processing residues into value-added products with economic, environmental, and social benefits (Mirabella et al., 2014; Amir & Alnagrat, 2026). Rather than being treated as disposal burdens, agro-industrial by-products are increasingly recognized as valuable secondary resources that can be reintegrated into productive systems as food ingredients, bio-based materials, animal feed, or bioenergy, thereby improving resource efficiency and supporting more resilient food systems (Lin et al., 2013; Mirabella et al., 2014).

Food waste valorization also contributes directly to the achievement of the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production), by promoting sustainable resource utilization, reducing environmental pollution, and encouraging more efficient production systems (United Nations, 2015). Consequently, waste valorization has evolved beyond conventional waste management into a strategic innovation approach that simultaneously enhances environmental sustainability, economic competitiveness, and sustainable entrepreneurship (Papargyropoulou et al., 2014). Within



circular food systems, this perspective encourages the utilization of food-processing by-products, such as tofu residue (okara), as renewable biological resources capable of generating commercially viable products while reducing waste generation and extending the productive life cycle of biomass resources (Jurgilevich et al., 2016; Ellen MacArthur Foundation, 2019). Consequently, integrating waste valorization into agro-industrial production represents a practical pathway for operationalizing circular economy principles while creating both environmental and economic value.

2.2 Tofu Residue (Okara) as an Agro-Industrial By-Product

Tofu residue, commonly referred to as okara, is a major by-product generated during the production of tofu and soy milk from soybeans. Although frequently treated as processing waste, okara retains a substantial proportion of the original soybean nutrients, including protein, dietary fiber, carbohydrates, lipids, vitamins, and essential minerals, making it a promising raw material for food and other value-added applications (Li et al., 2012; Vong & Liu, 2016). However, its high moisture content, typically exceeding 70%, accelerates microbial deterioration and considerably limits its shelf life, resulting in most fresh okara being utilized as low-value animal feed or discarded as organic waste (Colletti et al., 2020; Li et al., 2012). Inadequate management of this by-product may contribute to environmental problems, including unpleasant odors, increased biological oxygen demand, and organic pollution from decomposition (Vong & Liu, 2016).

Previous studies have demonstrated the technical feasibility of incorporating okara into a wide range of food products, including biscuits, crackers, noodles, bakery products, and functional foods, where its addition generally improves protein and dietary fibre content while simultaneously reducing agro-industrial food waste (Li et al., 2012; Colletti et al., 2020). Nevertheless, existing research has predominantly focused on product formulation, nutritional enhancement, and sensory evaluation, whereas comparatively little attention has been devoted to commercialization potential, business feasibility, and the economic viability of waste-derived food products. Moreover, despite the increasing recognition of food waste valorization within circular economy research, relatively few studies explicitly position okara utilization as a practical circular business model that simultaneously creates economic value and reduces food-processing waste in small and medium-sized agro-industrial enterprises (Geissdoerfer et al., 2017; Mirabella et al., 2014).

2.3 Zero-Waste Food Product Innovation

Zero-waste food innovation seeks to maximize resource utilization by transforming food-processing residues into commercially valuable products while minimizing waste generation throughout the production chain. Rather than treating by-products as waste requiring disposal, zero-waste approaches regard them as valuable secondary resources that can be reintegrated into food systems, thereby improving resource efficiency, extending material life cycles, and reducing environmental impacts (Papargyropoulou et al., 2014; Geissdoerfer et al., 2017). This perspective is consistent with circular economy principles, which emphasize retaining the value of biological resources through reuse, recycling, and resource recovery (Kirchherr et al., 2017; Jurgilevich et al., 2016). Recent bibliometric evidence further indicates that sustainability research is increasingly shifting toward resource recovery and circular



solutions, while applications involving non-durable food products remain comparatively underexplored, highlighting an important opportunity for innovation in food waste valorization and zero-waste product development (Amri et al., 2025).

The development of snack products from agro-industrial residues represents a promising application of zero-waste innovation because snack foods generally require relatively simple processing technologies, have broad consumer acceptance, and offer opportunities for small and medium-sized enterprises to develop value-added products. At the same time, consumers are increasingly demanding foods that combine nutritional quality with environmentally sustainable production practices, encouraging manufacturers to adopt circular product innovation strategies that integrate sustainability into product development (Aschemann-Witzel et al., 2019; van Loo et al., 2017). Accordingly, incorporating agro-industrial by-products into innovative snack products not only contributes to waste reduction and resource efficiency but also strengthens business competitiveness by responding to growing market demand for sustainable food products and supporting the commercialization of circular food innovations (Lüdeke-Freund et al., 2019).

2.4 Business Feasibility Assessment in Waste Valorization

Although technical feasibility is a prerequisite for developing waste-derived food products, successful commercialization ultimately depends on their economic viability and long-term business sustainability.

Indicators such as Cost of Goods Sold (COGS), Break-Even Point (BEP), Revenue–Cost (R/C) Ratio, and Return on Investment (ROI) are widely employed to evaluate the financial feasibility of small and medium-sized enterprises because they provide practical measures of production cost efficiency, profitability, operational performance, and investment returns (Brigham & Ehrhardt, 2017; Gittinger, 1982). In waste valorization initiatives, these indicators extend beyond conventional financial analysis by assessing whether circular innovations can generate sufficient economic incentives to encourage adoption and long-term implementation. Integrating financial feasibility analysis with product innovation therefore enables researchers to evaluate not only the technical success of transforming agro-industrial residues into value-added products but also the commercial readiness and scalability of circular business models (Bocken et al., 2016; Lüdeke-Freund et al., 2019). Such integrated assessments are increasingly recognized as essential for translating circular economy principles into practical entrepreneurial solutions capable of supporting sustainable food systems and strengthening the competitiveness of small and medium-sized agro-industrial enterprises (Geissdoerfer et al., 2017).

Despite growing interest in utilizing tofu residue for food applications, three important research gaps remain. Existing studies have predominantly concentrated on product formulation, nutritional enhancement, and sensory evaluation, while relatively few have integrated food product development with comprehensive business feasibility analysis. Accordingly, this study addresses these gaps by integrating zero-waste snack product development with financial feasibility assessment to demonstrate a practical waste valorization strategy that supports circular economy implementation and sustainable entrepreneurship.



METODE

3.1 Research Design

This study employed a prototype-based product development approach combined with a descriptive quantitative business feasibility assessment. Prototype development is widely recognized as an iterative process that enables researchers to progressively refine product designs through repeated testing and evaluation before commercialization, thereby improving product functionality and user acceptance (Ulrich & Eppinger, 2015). In parallel, descriptive quantitative analysis provides a systematic approach for evaluating business performance through objective financial indicators that support investment and commercialization decisions (Cooper et al., 2020). Accordingly, this research focused on transforming tofu residue into an innovative zero-waste snack product while simultaneously evaluating its economic viability as a waste valorization strategy. Product development was conducted iteratively through successive prototype refinement, whereas financial feasibility was assessed using standard business performance indicators commonly applied in small-scale food enterprises to evaluate production costs, profitability, operational efficiency, and investment performance (Brigham & Ehrhardt, 2017; Gittinger, 1982). Integrating prototype development with financial feasibility assessment provides a comprehensive framework for determining not only the technical feasibility of waste-derived food innovation but also its commercial readiness and potential contribution to circular economy implementation (Bocken et al., 2016).

3.2 Study Area

The study was conducted in Meureubo Subdistrict, West Aceh Regency, Indonesia, between March and June 2026. The study area was selected because it hosts several small-scale tofu producers that generate fresh tofu residue on a daily basis, providing a readily available source of raw material for product development. Product preparation was undertaken in collaboration with students of Universitas Teuku Umar, while product promotion and limited marketing activities were conducted within the university community and surrounding local markets.

3.3 Product Development

The development of RenyahLoka followed an iterative prototype development process consisting of three production cycles, resulting in six prototype variations. Fresh tofu residue served as the primary raw material and was combined with wheat flour, seasonings, and other supporting ingredients. A systematic set of steps is required to produce a crispy texture, good taste, and a marketable product (Bastomi et al., 2024). Furthermore, the water content in tofu residue is a crucial factor influencing the quality of processed products, so the draining process before mixing the dough plays a role in increasing crispiness and extending the product's shelf life (Rahmawati et al., 2020). Hence, each production cycle involved raw material preparation, moisture reduction through draining, ingredient mixing, dough preparation, shaping, frying, oil draining, cooling, and packaging as shown in Figure 1.

Following each production cycle, the prototypes were reviewed based on product texture, taste, appearance, packaging quality, and production consistency. Feedback obtained during



each evaluation was used to refine ingredient composition and processing procedures before the subsequent production cycle. The final prototype represented the formulation considered most suitable for commercial production.

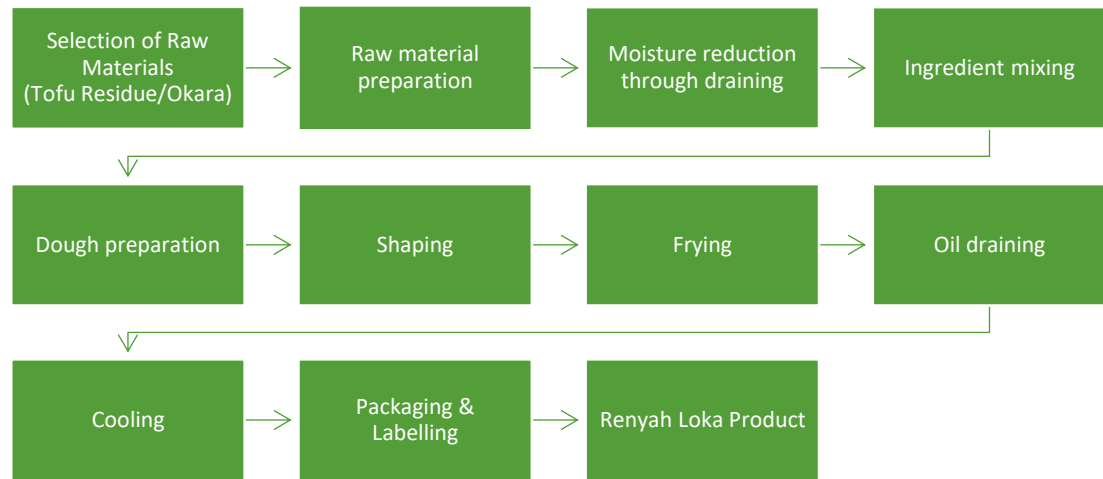


Figure 1. RenyahLoka product development steps.

3.4 Data Collection

Primary data consisted of production records, raw material consumption, production costs, selling prices, and financial transactions documented throughout the three production cycles. Observational records regarding prototype performance and production improvements were also maintained during each development stage.

Secondary data were obtained from government publications, statistical reports, and relevant scientific literature concerning tofu residue utilization, circular economy, waste valorization, and business feasibility assessment.

3.5 Business Feasibility Assessment

The commercial feasibility of the developed product was evaluated using standard financial indicators widely employed in business and investment analysis to assess production cost efficiency, profitability, operational performance, and investment viability (Brigham & Ehrhardt, 2017; Gittinger, 1982).

Cost of Goods Sold (COGS) was calculated as:

$$\text{COGS} = \frac{\text{Total Production Cost}}{\text{Number of Units Produced}}$$

where total production cost includes all direct material, direct labor, and manufacturing overhead costs incurred during product production (Horngren et al., 2018).

Total Revenue (TR) was calculated as:

$$\text{TR} = \text{P} \times \text{Q}$$

where P represents the selling price per package and Q denotes the number of packages sold (Brigham & Ehrhardt, 2017).



Business profit (Net Profit) was determined by subtracting total production cost from total revenue:

$$\text{Net Profit} = \text{TR} - \text{TC}$$

where TC represents the total production cost (Brigham & Ehrhardt, 2017).

The Break-Even Point (BEP) in units was calculated using a simplified BEP calculation, as:

$$\text{BEP} = \frac{\text{Total Production Cost}}{\text{Selling Price per Unit}}$$

to estimate the minimum production volume required for total revenue to equal total production cost under the assumptions adopted in this study (Gittinger, 1982).

The Revenue–Cost Ratio (R/C Ratio) was calculated as:

$$\text{R/C} = \frac{\text{Total Revenue}}{\text{Total Production Cost}}$$

which measures the economic efficiency of the business by comparing revenue generated with production costs (Gittinger, 1982).

The Return on Investment (ROI) was determined using:

$$\text{ROI}(\%) = \frac{\text{Net Profit}}{\text{Total Production Cost}} \times 100$$

to evaluate the profitability of the investment relative to the production cost incurred (Brigham & Ehrhardt, 2017).

Business feasibility was interpreted according to established financial criteria. An R/C Ratio greater than 1 indicates that the business generates revenues exceeding production costs and is therefore considered economically feasible, whereas higher ROI values indicate stronger investment performance and greater financial attractiveness (Gittinger, 1982; Brigham & Ehrhardt, 2017).

3.5 Data Analysis

All production and financial data were analyzed using descriptive quantitative analysis to summarize the technical and economic performance of the developed product. Product development outcomes were synthesized narratively, whereas financial performance indicators, including Cost of Goods Sold (COGS), Total Revenue (TR), Break-Even Point (BEP), Revenue–Cost (R/C) Ratio, and Return on Investment (ROI), were calculated using spreadsheet-based analysis to ensure systematic and transparent computation (Cooper et al., 2020). Descriptive analysis is appropriate for studies that aim to summarize observed data and evaluate performance without testing causal relationships or statistical hypotheses (Creswell & Creswell, 2018). The resulting financial indicators were subsequently interpreted to assess the commercial feasibility of the proposed waste valorization strategy and its potential application within small-scale sustainable food enterprises, where financial viability constitutes an important dimension of successful circular business implementation (Lüdeke-Freund et al., 2019).



RESULT

4.1 Product Development and Waste Valorization

The development of RenyahLoka demonstrated the technical feasibility of converting tofu residue into a commercially attractive snack product through an iterative prototype development process. Six prototypes were produced across three production cycles, enabling gradual refinement of ingredient composition, processing techniques, product texture, and packaging quality. The iterative approach facilitated continuous improvements after each production cycle, resulting in a final product exhibiting desirable crispness, sensory appeal, and production consistency. Such iterative prototype refinement is widely recognized as an effective approach for improving product quality and functionality prior to commercialization (Ulrich & Eppinger, 2015). The processes and product can be seen in Figure 2.

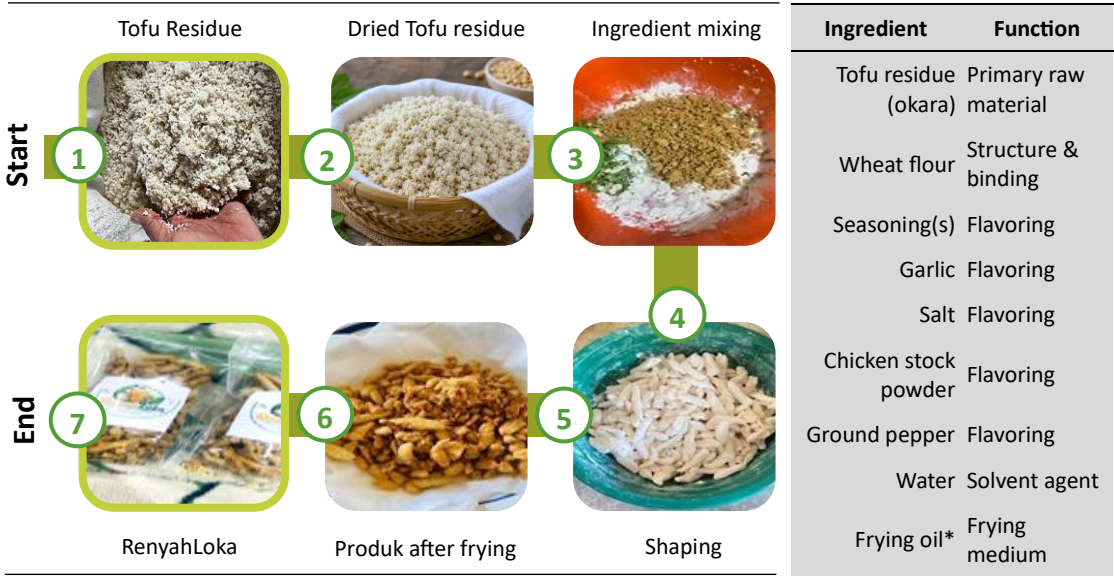


Figure 2. RenyahLoka Ingredient and production workflow.

The production workflow illustrates the practical application of waste valorization principles by converting an underutilized agro-industrial by-product into a marketable food product. The production system reintegrates it into the food value chain, thereby extending resource utilization, reducing organic waste generation, and supporting circular food production systems (Geissdoerfer et al., 2017; Mirabella et al., 2014). This approach demonstrates how value can be recovered from food-processing residues through product innovation while contributing to more resource-efficient and sustainable agro-industrial practices.

Table 1. Product evaluation matrix

No.	Description	Value <i>(The accepted value ranged from 1-10)</i>					
		P1	P2	P3	P4	P5	P6
1	Product texture	6	7	6	7	8	7
2	Taste	6	6	7	8	8	7
3	Appearance	6	7	6	6	7	7
4	Packaging quality	8	8	8	8	8	8
Average		6.5	7	6.75	7.25	7.75	7.25



Table 1 presents the evaluation results of the six RenyahLoka prototypes (P1–P6) based on product texture, taste, appearance, and packaging quality using a 1–10 scale. The average scores ranged from 6.50 to 7.75, indicating generally favorable evaluations across the prototypes. P5 obtained the highest overall average score (7.75), followed by P4 and P6 (7.25 each), P2 (7.00), P3 (6.75), and P1 (6.50). Packaging quality received a consistent score of 8 across all prototypes, indicating that this attribute remained stable throughout the product-development process. In contrast, the greatest variation occurred in texture and taste, with scores ranging from 6 to 8. Based on the overall evaluation, P5 demonstrated the most favorable combination of product attributes and was therefore selected as the preferred prototype for subsequent development. The ingredient of P5 is presented in Table 2.

Table 2. The best composition of RenyahLoka (P5)

Ingredient	Function	Quantity
Tofu residue (okara)	Primary raw material	1000 gr
Wheat flour	Structure & binding	500 gr
Garlic	Flavoring	30 gr
Salt	Flavoring	15 gr
Chicken stock powder	Flavoring	15 gr
Ground pepper	Flavoring	5 gr
Water	Solvent agent	200 ml
Frying oil*	Frying medium	1000 ml

These findings are consistent with previous studies demonstrating that tofu residue (okara) is a nutritionally valuable ingredient suitable for the development of value-added food products because of its high protein and dietary fiber content (Li et al., 2012; Vong & Liu, 2016; Colletti et al., 2020).

4.2 Product Profile and Market Positioning

The final product developed in this study, marketed under the brand name RenyahLoka, is a crispy snack produced primarily from tofu residue (okara) through a zero-waste product development approach. The brand name combines the Indonesian word *renyah* (crispy) with *loka*, meaning "place" or "world," reflecting the concept of providing an enjoyable snacking experience while promoting environmental sustainability. Consistent with this concept, the product adopts the tagline “RenyahLoka: Crispy Taste, Greener Future” (translated from the Indonesian slogan “Renyah Nikmat, Ramah Lingkungan”), emphasizing the integration of product quality with environmental responsibility.

The target market consists primarily of university students and general consumers seeking affordable snack products with environmentally responsible characteristics. The market potential is supported by increasing consumer awareness of sustainable food products, growing demand for affordable ready-to-eat snacks, and the unique value proposition of utilizing tofu-processing residues as the principal raw material (Aschemann-Witzel et al., 2019; Vong & Liu, 2016). The product was offered at a retail price of IDR 5,000 per package, positioning it within the affordable snack segment while maintaining attractive profitability. From the supply perspective, the abundant availability of tofu residue from local tofu



producers, together with relatively simple production processes and low production costs, provides favorable conditions for future business expansion.

To support commercialization, the product was packaged in labeled stand-up pouch packaging designed to improve product protection and market appeal. Marketing activities combined conventional and digital approaches, including direct selling, word-of-mouth promotion, WhatsApp, Instagram, and digital promotional materials. Product distribution initially focused on the Meureubo District and the surrounding community of Teuku Umar University, representing an accessible local market for testing consumer acceptance prior to potential expansion into broader regional markets. Collectively, these commercialization strategies complement the technical and financial feasibility demonstrated in this study by illustrating the practical implementation of waste valorization within a small-scale circular food enterprise (Geissdoerfer et al., 2017; Lüdeke-Freund et al., 2019).

4.3 Business Feasibility Assessment

4.3.1 Financial analysis

The financial performance of RenyahLoka was evaluated using production cost, cost of goods sold (COGS), total revenue, projected profit, and break-even point (BEP). These indicators provide an initial assessment of the economic performance of the developed waste-derived snack product and establish the basis for subsequent business feasibility evaluation. Table 3 summarizes the financial performance of one production cycle.

Table 3. The financial performance of one production cycle

Indicator	Value
Production volume	100 packages
Total production cost	IDR 194,000
Cost of Goods Sold (COGS)	IDR 1,940/package
Selling price	IDR 5,000/package
Total revenue	IDR 500,000

The production cost of IDR 194,000 generated 100 packages, resulting in a COGS of IDR 1,940 per package. With a selling price of IDR 5,000, each package generated a gross margin of approximately IDR 3,060 before considering future operational expansion costs.

The projected total revenue reached IDR 500,000, producing a net profit of IDR 306,000 during a single production cycle. These results indicate that the production process successfully converted a low-value agro-industrial by-product into a commercially marketable product while maintaining relatively low production costs. The favorable financial performance was primarily attributable to the abundant availability of tofu residue, simple processing techniques, and the limited capital investment required for production.

The calculated break-even point of 39 packages indicates that only 39% of the total production volume must be sold to recover all production costs. Consequently, approximately 61% of the remaining production contributes directly to business profit, reducing financial risk during early-stage commercialization.



Overall, the financial indicators suggest that tofu residue can be transformed into a value-generating product capable of supporting income generation while simultaneously reducing agro-industrial waste. These findings demonstrate that waste valorization can create both environmental and economic benefits within small-scale food processing systems.

4.3.2 Business Feasibility Analysis

Although positive financial performance is an essential prerequisite, the long-term viability of an innovation depends on its overall business feasibility. Therefore, the commercial potential of RenyahLoka was further evaluated using the Revenue–Cost (R/C) Ratio and Return on Investment (ROI), which are widely employed indicators for assessing the economic sustainability of small-scale food enterprises. Table 4 presents the feasibility analysis results.

Table 4. Business Feasibility Indicators

Indicator	Formula	Value	Interpretation
Revenue–Cost Ratio (R/C)	Total Revenue ÷ Total Cost	2.58	Economically feasible (R/C > 1)
Return on Investment (ROI)	(Net Profit ÷ Total Cost) × 100	157.73%	High investment return

The calculated R/C Ratio of 2.58 indicates that every IDR 1.00 invested in production generated IDR 2.58 in revenue. According to conventional business feasibility criteria, an R/C Ratio greater than one signifies that the enterprise is economically feasible because total revenue exceeds total production costs. The observed value therefore suggests that the proposed waste valorization model possesses strong commercial potential for small-scale implementation. Similarly, the ROI of 157.73% demonstrates a high level of investment efficiency. This result indicates that the initial production expenditure generated returns substantially exceeding the invested capital during a single production cycle. Such performance reflects the combined effects of low raw material costs, efficient production procedures, and favorable market pricing.

From a broader perspective, these findings reinforce the argument that waste valorization initiatives can achieve both environmental and economic objectives simultaneously. Numerous circular economy initiatives struggle to move beyond pilot implementation because of weak financial performance. In contrast, the positive R/C Ratio and ROI observed in this study suggest that the proposed business model possesses sufficient economic attractiveness to encourage adoption by small and medium-sized enterprises (SMEs), community-based food processors, and entrepreneurial start-ups.

The integration of financial profitability with waste reduction also supports the fundamental principles of the circular economy, in which biological resources remain within productive systems for as long as possible while generating continuous economic value. Consequently, the commercialization of tofu residue into RenyahLoka represents not only an innovative food product but also a practical example of a circular business model capable of simultaneously enhancing resource efficiency, reducing organic waste, and supporting sustainable entrepreneurship.



DISCUSSION

The present findings support the growing body of literature suggesting that agro-industrial by-products can be transformed into economically valuable products while simultaneously reducing environmental burdens, as done by many researchers such as Redha et al. (2026), Purwitasari et al. (2026), and Fahriza et al. (2026). Previous studies on tofu residue have demonstrated the technical feasibility of incorporating tofu residue into various food products because of its favorable nutritional composition and functional properties (Li et al., 2012; Vong & Liu, 2016; Colletti et al., 2020). However, relatively few studies have examined whether these innovations are commercially viable or capable of supporting sustainable business development. The present study contributes additional empirical evidence by demonstrating that a waste-derived snack product can achieve positive financial performance while utilizing relatively simple processing technologies. This finding extends the existing literature by integrating technical product development with commercial feasibility assessment, thereby addressing an important gap in food waste valorization research.

From a circular economy perspective, the utilization of tofu residue exemplifies waste valorization by extending the productive life of biological resources rather than allowing them to become waste. This approach reflects one of the core principles of the circular economy, namely maintaining the highest possible value of materials and resources through reuse and value recovery (Kirchherr et al., 2017; Geissdoerfer et al., 2017). Furthermore, converting tofu residue into a marketable snack contributes to resource efficiency by recirculating nutrients within the food system and reducing dependence on virgin food resources, thereby supporting the transition from linear production systems toward regenerative and circular food value chains (Jurgilevich et al., 2016; Mirabella et al., 2014). The findings therefore provide practical evidence that food-processing residues can function as valuable secondary resources rather than disposal burdens when supported by appropriate product innovation.

Moreover, integrating financial feasibility assessment into product development substantially strengthens the practical relevance of waste valorization research. Previous studies on circular business models emphasize that environmental innovations are unlikely to achieve widespread implementation unless they are supported by economically viable business models capable of generating sustainable value for producers and consumers (Bocken et al., 2016; Lüdeke-Freund et al., 2019). The positive business performance observed in this study reinforces the argument that environmental sustainability and commercial profitability are complementary rather than competing objectives. By demonstrating that tofu residue can simultaneously generate environmental, nutritional, and economic value, the present study provides empirical support for the implementation of sustainable entrepreneurship within circular food systems and illustrates how waste valorization can contribute to both environmental protection and local economic development (Geissdoerfer et al., 2017).

5.1 Practical Implications

The findings provide several practical implications for stakeholders involved in food processing and sustainable entrepreneurship. For tofu producers, converting processing residues into value-added snack products offers an opportunity to diversify income while reducing waste



management costs. For small and medium-sized enterprises (SMEs), the relatively low investment requirements and favorable profitability indicators suggest that similar business models may be economically accessible. These findings support the growing emphasis on circular business models, which encourage enterprises to create economic value by retaining materials within productive systems while simultaneously reducing environmental impacts (Bocken et al., 2016; Lüdeke-Freund et al., 2019). Such approaches are particularly relevant for SMEs because they promote resource efficiency, stimulate innovation, and strengthen business resilience through locally available waste resources (Geissdoerfer et al., 2017).

From an educational perspective, the study also demonstrates the effectiveness of entrepreneurship-based learning in integrating sustainability concepts with practical business development. Entrepreneurship education that incorporates experiential learning and sustainability-oriented innovation has been shown to strengthen students' entrepreneurial competencies while fostering awareness of environmental and social responsibility (Lans et al., 2014; Neck et al., 2021). By engaging students in the development and commercialization of waste-derived products, educational institutions can promote sustainable entrepreneurship while encouraging innovative solutions to local environmental challenges. Consequently, integrating circular economy principles into entrepreneurship education may help cultivate future entrepreneurs capable of creating businesses that simultaneously generate economic, environmental, and social value (Shepherd & Patzelt, 2011).

5.2 Contribution to Circular Economy and Sustainable Food Systems

Beyond its commercial potential, the development of RenyahLoka contributes to broader sustainability objectives by supporting circular food systems through waste reduction, resource recovery, and local value creation. The conversion of tofu residue into food products aligns with the principles of the circular economy by maintaining the utility of biological resources for as long as possible before final disposal.

The study also contributes to Sustainable Development Goal 12 (Responsible Consumption and Production) by promoting resource-efficient production practices and reducing food-processing waste. Furthermore, the proposed business model illustrates how localized waste valorization initiatives may strengthen regional circular economies while creating new entrepreneurial opportunities. Consequently, the research provides practical evidence that small-scale food innovations can simultaneously generate economic returns, reduce environmental impacts, and support sustainable community development.

CONCLUSION

This study demonstrated the technical and economic feasibility of transforming tofu residue into a marketable zero-waste snack product through an iterative prototype development process. Six product prototypes were successfully developed across three production cycles, resulting in the final RenyahLoka product. Financial evaluation indicated favorable business performance, with a Cost of Goods Sold (COGS) of IDR 1,940 per package, a Break-Even Point (BEP) of 39 packages, a Revenue–Cost (R/C) Ratio of 2.58, and a Return on Investment (ROI) of 157.73%, confirming the commercial potential of the proposed waste valorization strategy.



Beyond demonstrating economic feasibility, this study contributes to the growing body of knowledge on waste valorization and circular food systems by illustrating how agro-industrial by-products can be converted into commercially viable food products through relatively simple processing technologies. By integrating product development with business feasibility assessment, the research extends previous studies that primarily focused on product formulation or nutritional characteristics, thereby providing a more comprehensive perspective on the commercialization of waste-derived food innovations. This contribution aligns with the broader objectives of the circular economy, which emphasize retaining the value of biological resources through resource recovery, waste valorization, and sustainable business innovation (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

The findings also have important practical implications. For tofu producers and small and medium-sized enterprises (SMEs), the proposed business model offers an opportunity to diversify income while reducing agro-industrial waste. For universities and entrepreneurship programs, the study demonstrates the value of experiential learning that integrates sustainability principles with product innovation and business development. More broadly, the study supports the implementation of circular economy principles by promoting resource efficiency, extending the productive use of biological materials, and contributing to more sustainable local food systems through economically viable circular business models (Bocken et al., 2016; Lüdeke-Freund et al., 2019).

Nevertheless, several limitations should be acknowledged. The study was conducted at a small production scale within a single geographical area and focused primarily on financial feasibility. It did not include laboratory analyses of nutritional composition, shelf-life testing, formal sensory evaluation, or environmental performance assessment. Consequently, the findings should be interpreted as preliminary evidence of the commercial potential of tofu residue valorization rather than as a comprehensive product evaluation.

Future research should expand this work by incorporating physicochemical and nutritional analyses, consumer acceptance studies using standardized sensory evaluation methods, shelf-life assessment, Life Cycle Assessment (LCA), and techno-economic analysis at larger production scales. Comparative studies involving different agro-industrial by-products and broader market settings would also provide valuable insights into the scalability and long-term sustainability of circular food innovation. Such multidisciplinary approaches are increasingly recommended to evaluate the environmental, economic, and technical performance of circular food systems comprehensively and to support evidence-based implementation of waste valorization strategies (Hauschild et al., 2018; ISO, 2006).

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