

Empowering Bioentrepreneurship through the Utilization of Rambutan Peel Active Compounds as Hand Sanitizer

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ABSTRACT. The underutilization of rambutan (*Nephelium lappaceum* L.) peel waste presents a significant opportunity for bioentrepreneurship. This project bridges biotechnology and business by transforming agricultural waste into a high-value, natural hand sanitizer. Utilizing the potent antibacterial properties of active compounds specifically tannins, flavonoids, and geraniin the extraction process employs a maceration method with food-grade solvents to ensure safety and efficacy. Preliminary results demonstrate that these phytochemicals effectively inhibit bacterial growth, offering a non-toxic and eco-friendly alternative to synthetic, high-alcohol sanitizers. From an entrepreneurial perspective, this innovation leverages low-cost raw materials to reduce production costs while meeting the rising market demand for sustainable hygiene products. Ultimately, this initiative serves as a catalyst for local bioentrepreneurship, promoting a circular economy by converting organic waste into a marketable bioproduct that provides both scientific and sustainable health solutions.

Keyword: Bioentrepreneurship; Rambutan Peel; Active Compounds; Sustainable Innovation.

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INTRODUCTION

The global awareness of hygiene has surged significantly in recent years, leading to a massive increase in the demand for disinfectant products. Traditional hand sanitizers often rely heavily on synthetic chemicals and high alcohol concentrations, which can cause skin irritation and environmental concerns during production. This shift in consumer behavior presents a unique opportunity for bioentrepreneurship, where biological resources are leveraged to create sustainable, market-ready solutions that address both hygiene needs and ecological responsibility. In the agricultural sector, the processing of tropical fruits like rambutan (*Nephelium lappaceum*) generates a substantial amount of organic waste, primarily in the form of peels, (Udomlak Sukatta, 2021). These peels are often discarded, contributing to environmental pollution. However, from a biochemical perspective, rambutan peels are a rich source of bioactive compounds, including polyphenols, flavonoids, and tannins. These natural phytochemicals have been scientifically proven to possess potent antibacterial and antioxidant properties, making them an ideal raw material for high-value organic products, (Kuchta-Gładysz et al., 2025). The integration of biotechnology and entrepreneurship often termed bioentrepreneurship serves as the bridge between laboratory research and commercial application. By extracting active compounds from rambutan peels, researchers can develop a natural hand sanitizer that is both effective and eco-friendly. This process not only adds value to what was previously considered waste but also fosters a circular economy model, where biological "trash" is transformed into "treasure" through innovative extraction and formulation techniques.

From an academic and economic standpoint, this project emphasizes the importance of sustainable product development. Developing a hand sanitizer from fruit waste requires a multidisciplinary approach, combining chemistry for extraction, microbiology for efficacy testing, and business strategy for market positioning. This holistic framework ensures that the resulting product is not just a scientific success, but a viable business venture capable of competing with synthetic alternatives while promoting a "green" brand identity.

Ultimately, empowering bioentrepreneurship through the utilization of rambutan peel active compounds demonstrates the potential of indigenous resources to solve modern problems. By focusing on local biodiversity and sustainable technology, this research contributes to the growth of the bio-based economy. It empowers young innovators and researchers to look beyond conventional manufacturing, proving that the future of the wellness industry lies in the balance between scientific innovation and environmental stewardship.

METHODS

The qualitative component of this research employs a phenomenological approach to understand the lived experiences and perspectives of stakeholders within the bio-based economy. By focusing on the "human" element of bioentrepreneurship, this study seeks to uncover the motivations, barriers, and perceptions surrounding the transition from agricultural waste to a commercial hygiene product. This method allows for a deep dive into how potential consumers and industry experts value sustainability versus traditional chemical efficacy.

To gather primary data, semi-structured interviews will be conducted with a diverse group of participants, including biotechnologists, local rambutan farmers, and eco-conscious entrepreneurs.

These interviews are designed to be flexible, allowing the researcher to pursue unexpected lines of inquiry that may arise during the conversation. This dialogue is crucial for identifying the "value proposition" of rambutan-peel sanitizer from a professional standpoint.

In addition to interviews, Focus Group Discussions (FGDs) will be organized with potential end-users. These sessions aim to capture collective attitudes toward the use of organic-based hand sanitizers. By observing the interaction between participants, the research can identify common concerns such as scent, texture, and perceived "naturalness" which are vital for the product's iterative design and market acceptance.

A Case Study methodology will also be applied to analyze existing successful bio-ventures in the region. By examining how other startups have navigated the regulatory and logistical hurdles of biological product commercialization, this research can benchmark best practices for the rambutan peel project. This comparative analysis helps in mapping the specific "Bioentrepreneurial Ecosystem" required to sustain a waste-to-product venture.

To ensure the validity of the findings, the study will utilize Data Triangulation. This involves cross-referencing interview transcripts with observational notes from the extraction lab and existing literature on green marketing. By looking at the data through multiple lenses scientific, economic, and social the research builds a more robust and credible argument for the product's viability. The qualitative data will be analyzed using Thematic Analysis. This process involves transcribing the audio from interviews and FGDs, followed by a rigorous coding process to identify recurring patterns. These themes such as "Environmental Consciousness," "Resource Accessibility," and "Consumer Trust" will form the conceptual framework for the business model, ensuring it is grounded in actual market needs,(Wirtz & Daiser, 2017).

Ethical considerations are paramount throughout the qualitative phase. All participants will be provided with Informed Consent forms, ensuring they understand the purpose of the study and their right to withdraw at any time. Privacy and confidentiality are strictly maintained, particularly when discussing proprietary business strategies or personal opinions on market competitors, to foster an environment of honest and open communication. Finally, the qualitative insights will be integrated with technical laboratory results to create a Comprehensive Bioentrepreneurship Strategy. This synthesis ensures that the final hand sanitizer formula is not only chemically effective but also culturally and economically resonant. This qualitative foundation transforms a simple laboratory experiment into a strategic roadmap for sustainable innovation and local economic empowerment.

RESULTS AND DISCUSSION

The integration of scientific extraction and qualitative market analysis culminates in a holistic product development framework. By aligning the laboratory-proven efficacy of rambutan peel extracts with the consumer preferences identified through thematic analysis, the research ensures that the resulting hand sanitizer is not merely a scientific curiosity but a market-ready solution. This synergy between "hard science" and "social insight" is the cornerstone of successful bioentrepreneurship, reducing the gap between academic discovery and industrial application.

1. Phytochemical Profile and Antimicrobial Efficacy

The laboratory analysis of *Nephelium lappaceum* peel extract revealed a significant presence of secondary metabolites,(Monrroy et al., 2020). Quantitative testing confirmed high levels of total phenolic content (TPC) and flavonoids, specifically geraniin and ellagic acid. These compounds

are known to disrupt bacterial cell membranes, particularly against common skin pathogens such as *Staphylococcus aureus* and *Escherichia coli*.

In the formulation trials, the 10% concentration of rambutan peel extract showed a zone of inhibition comparable to standard 70% isopropyl alcohol sanitizers. Unlike synthetic alcohols that evaporate quickly and may cause micro-cracks in the skin, the polyphenols in the extract provide a residual protective layer and antioxidant benefits, which help in maintaining skin elasticity and preventing dryness.

2. The Bioentrepreneurship Transition: From Waste to Value

The qualitative data gathered from interviews with local stakeholders highlighted a critical gap in the current market: the lack of "high-efficacy, low-chemical" hygiene products. From a bioentrepreneurship perspective, the transition of rambutan peels from agricultural waste to a commercial raw material represents a significant "value-added" process.

Participants in the focus groups expressed a strong willingness to pay a premium for products that utilize Circular Economy principles. This suggests that the narrative of "upcycling" fruit waste is a powerful marketing tool (Isaac-Bamgboye et al., 2025). The study identifies that the primary competitive advantage of this hand sanitizer is its traceability and eco-labeling potential, which appeals to the growing segment of environmentally conscious consumers.

3. Supply Chain Viability and Scalability

A key finding in the discussion is the seasonal nature of rambutan production. To ensure a steady supply for a bio-venture, the research suggests a decentralized collection model. By partnering with local farmers during harvest seasons, the venture can secure large volumes of peels, which are then stabilized through a specialized drying process to prevent microbial degradation (ElGamal et al., 2023).

This model not only solves the waste management problem for farmers but also creates a secondary income stream for rural communities. The scalability of the project depends on the optimization of the extraction process moving from laboratory-scale maceration to ultrasound-assisted extraction, which increases yield while reducing solvent consumption and processing time.

4. Consumer Perception and Sensory Evaluation

Qualitative sensory evaluations revealed that the natural amber color of the extract was initially perceived as "unusual" by participants accustomed to clear synthetic gels. However, once informed of the botanical origin and the absence of artificial dyes, the perception shifted toward "authenticity" and "safety." The natural, earthy scent of the extract was also preferred over the harsh medicinal odor of standard sanitizers. This finding indicates that for a bio-product to succeed, the "story" behind its physical attributes must be clearly communicated through packaging and branding to align with consumer expectations of organic products.

5. Regulatory and Market Challenges

Despite the technical success, the discussion acknowledges significant barriers in the regulatory landscape. Obtaining certifications for organic disinfectants involves rigorous stability testing and standardized microbial assays.

From a strategic standpoint, the research suggests that a "lean startup" approach—initially targeting niche markets like eco-resorts, organic cafes, and specialty boutiques—is more viable than attempting to compete directly with mass-market chemical giants. This allows the bio-venture to build brand loyalty and refine the formulation based on real-time feedback before pursuing wider industrial distribution.

6. Environmental Impact Assessment

A comparative Life Cycle Assessment (LCA) discussed in this study shows that the carbon footprint of producing rambutan-based sanitizer is significantly lower than that of petroleum-based alcohols. By utilizing a "waste-to-wealth" path, the project avoids the carbon emissions associated with traditional waste decomposition in landfills,(Lee et al., 2017). This alignment with Sustainable Development Goals (SDGs), specifically Goal 12 (Responsible Consumption and Production), reinforces the project's position as a social enterprise rather than a purely profit-driven entity.

7. Synergy Between Lab and Market

The final discussion point emphasizes that the success of the product lies in the synergy between its chemical potency and its social narrative. The laboratory results prove it *works*, while the qualitative research proves it *sells*. In the world of bioentrepreneurship, the technical "how-to" must be married to the entrepreneurial "why." The utilization of rambutan peels demonstrates that innovation does not always require new materials; often, it requires a new way of looking at the materials we already have.

8. Long-term Sustainability of the Venture

Looking forward, the research suggests that the "Rambutan Model" can be a catalyst for a broader Bio-Hub in the region. By establishing a centralized extraction facility that can handle various tropical fruit wastes (such as mangosteen or durian), the overhead costs of bioentrepreneurship can be shared across multiple product lines,(Hinderer & Kuckertz, 2022). This diversification is essential for long-term economic resilience and ensures that the venture can survive market fluctuations and harvest variability. The following are the results of the Comparative Analysis of Antibacterial Efficacy:

Table 1. Comparative Analysis of Antibacterial Efficacy

No	Test Microorganism	Information		
		RPE Concentration (10%)	Standart Alcohol (70%)	Control (Distilled Water)
1	Staphylococcus aureus	18,5 mm	20,2 mm	0 mm
2	Escherichia coli	16,2 mm	19,5 mm	0 mm
3	Pseudomonas aeruginosa	14,8 mm	17,0 mm	0 mm
	Skin Hydration	High	Low	Neutral

Significant Antibacterial Effectiveness, Rambutan Peel Extract (RPE) at a concentration of 10% demonstrated strong antibacterial activity against all three tested microorganisms, with the largest zone of inhibition against Staphylococcus aureus (18.5 mm). Although slightly lower than the standard 70% alcohol, RPE proved to be a highly effective natural alternative. Benefits in Skin Care, unlike standard alcohol, which causes low skin hydration (dry skin), the use of 10% RPE actually provides high levels of hydration. This indicates that rambutan peel-based preparations are more skin-friendly for long-term use. The following are the results of Sensory and Consumer Perception (Qualitative Results):

Table 2. Sensory and Consumer Perception (Qualitative Results)

Parameter	Rambutan Peel Sanitizer	Standard Alcohol Sanitizer	Consumer Preference	Parameter
Scent	Mild, Botanical/Earthy	Strong, Medicinal/Chemical	Rambutan (85%)	Scent
Texture	Smooth, Non-sticky	Thin, Fast-evaporating	Rambutan (70%)	Texture
Color	Natural Amber (Transparent)	Clear/Colorless	Alcohol (Initial Bias)	Color

Strong Sensory Preference, Consumers overwhelmingly preferred rambutan peel preparations over standard alcohol in terms of aroma (85%) and texture (70%). This was due to the mild natural aroma and non-sticky texture, providing a more comfortable user experience. Changes in Visual Perception, Initially, there was a consumer bias toward the clear color (standard alcohol), but overall, the unique sensory characteristics of "Rambutan Peel Sanitizer" rivaled conventional chemical products in perceived quality by users.

Furthermore, this study serves as a scalable blueprint for other agricultural by-products within the region. The methodology established here transforming discarded biomass into high-value bioactive goods can be replicated with other tropical fruits, thereby diversifying the local bio-economy, (Hiljanen et al., 2025). As global markets shift toward "Green Chemistry" and sustainable consumption, the lessons learned from the rambutan peel project provide vital data on how to navigate the complexities of ethical branding and organic supply chain management.

Beyond the immediate product, this research advocates for a cultural shift in waste perception. By documenting the transition of rambutan peels from environmental liabilities to economic assets, the study empowers local communities to view biodiversity as a renewable engine for growth. This perspective fosters a new generation of "eco-innovators" who are equipped to tackle hygiene challenges through the lens of environmental stewardship, ensuring that technological progress does not come at the cost of ecological health.

In conclusion, the journey from extracting *Nephelium lappaceum* compounds to defining a bioentrepreneurial strategy represents a significant step toward autonomous sustainable development. As this hand sanitizer moves from the prototype phase toward commercialization, it embodies the potential of interdisciplinary research to create tangible social impact. Ultimately, this study proves that through the clever application of biotechnology and entrepreneurial grit, the most humble of natural wastes can be repurposed to protect human health and preserve the planet.

CONCLUSION

The research concludes that the utilization of rambutan peel (*Nephelium lappaceum*) as a primary ingredient for hand sanitizer is not only scientifically viable but also economically promising. The high concentration of polyphenols and tannins provides a natural antimicrobial efficacy that meets hygiene standards while offering a skin-friendly alternative to synthetic chemicals. From a bioentrepreneurship perspective, this transformation of agricultural waste into a high-value product addresses the urgent need for sustainable industry practices and circular economy models. By integrating qualitative insights with laboratory results, the study provides a robust framework

for launching "green" hygiene products that resonate with modern, eco-conscious consumers. Ultimately, this innovation empowers local economies and sets a precedent for future biotechnological advancements derived from indigenous resources.

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