

Review Circular Economy And Valorization Of Shrimp Shell Waste: Sustainable Approach Framework In Banten Province

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Abstract

This paper examines sustainable solutions for the recycling, compounding, and valorizing of food byproducts for reintroduction into the industrial chain and circular economy, which are significant challenges. They are still being studied in the technological and scientific fields. Therefore, every effort has been made and directed towards consolidating the overall management of these materials to avoid negative impacts on the environmental and economic losses, which can provide added value to these byproducts, especially fishery waste focused on shrimp shell waste. Shrimp and the processing of the two other main crustaceans (lobster and crab) are often associated with unavoidable byproducts, high waste disposal costs, and disturbed public and environmental health. The literature that reported experiments on producing bioactive compounds from crustacean waste was sourced from Google Scholar and published in 2018-present. This problem explains that tiny quantities still extract high-value biomaterial products (chitin, lipids, minerals). The problem explains that tiny quantities still extract high-value biomaterial products (chitin, lipids, minerals). This also occurs due to the need for adequate and standardized technology to convert it into valuable materials.

Keywords: Shrimp waste, Chitin, Circular economy, SDGs

INTRODUCTION

As we all know, as in the past, even now and in the future, sustainable solutions for the recycling, compounding and valorization of food byproducts for reintroduction into the industrial chain and circular economy are significant challenges and are still being studied in the technological and scientific fields. Therefore, every effort has been tried and put to be directed towards consolidating the overall management of these materials to avoid negative impacts on the environmental and economic losses, which can provide added value to these byproducts, especially fishery waste focused on shrimp shell waste (Gómez et al., 2021). All the report evidence states that the byproduct from seafood waste, namely shrimp shells, has excellent material characteristics and benefits of high value (protein/peptides, chitin/chitosan, pigments, minerals, and vitamins) (Suryawanshi & Eswari, 2022). This is the main advantage if we can utilize and transform with a focus on transitioning to environmentally friendly technology and a circular economy in order to make our planet clean and our society prosperous in contributing to sustainable development (Fritsche et al., 2020; Gómez et al., 2021). Shrimp is one of the most dominant fishery products cultivated in the world, especially in Indonesia (Priyanga et al., 2023). In 2020, shrimp production reached 5.03 million globally and is estimated to grow to 7.28 million tons by 2025, with a compound annual growth rate (CAGR) of 6.1% from 2020 to 2025 (Nirmal et al., 2020). Within this number, Indonesia contributed 1.48 million tons (21%), estimated to have a value of IDR 92.69 trillion (Janggur et al., 2023). Shrimp production has become the leading marine commodity, significantly contributing to Indonesia's economic growth (Fatimah et al., 2020). Until now, only two species in Indonesia are widely cultivated: tiger and name prawns. The provinces with the most shrimp producers in Indonesia are West Java Province and Lampung Province, Precisely in Tulang Bawang District (Alsya et al., 2023). According to the SUSENAS data reported by the Indonesia Central Statistics Agency in March 2016, the pattern of consumption of fresh shrimp in households in Indonesia is 9.58kg/capita/year (Arthatiani et al., 2018). The Shrimp processing industry produces 50-60% waste of the catch volume (Hu et al., 2020). The higher the shrimp production and consumption, the possibility of the

formation of production waste also increases. The bioproducts remaining from seafood consumption, especially shrimp shells, are an ecological challenge because the shrimp shell waste continues to increase gradually and lasts a long time. It also causes the waste to accumulate in the sea and, over time, become rotten (Priyanga et al., 2023). Worldwide, seafood companies have abandoned vast amounts of shrimp shells as waste (Teli & Sheikh., 2012). Shrimp and the processing of the two other main crustaceans (lobster and crab) are often associated with unavoidable byproducts, high waste disposal costs, and disturbed public and environmental health. This problem explains that tiny quantities still extract high-value biomaterial products (chitin, lipids, minerals).

This also occurs due to the lack of adequate and standardized technology to convert it into valuable materials (Zhang et al., 2023; Teli, Sheikh., 2012). This review article aims to show the potential of shrimp shell byproducts as renewable industrial raw materials to implement a circular economy. It also aims to address environmental, social, and economic problems and support sustainable development goals (SDGs). While the consumption of crustacean crustaceans is increasing, an increasing number of shellfish shells is also anticipated. In particular, the shellfish processing industry wastes approximately 50-60% of catch volume (Hu et al., 2020). Increasing shellfish waste can lead to ecological challenges, such as disposal costs. While the leftover shells are considered waste, valuable molecules such as chitin, peptides, and minerals are present in the waste. They can be extracted for other uses, such as natural plant growth enhancers, food preservatives, and wound healing products.

LITERATURE REVIEW

Crustacean byproducts contain materials that are useful for various applications. This means the byproducts can be further processed to procure valuable compounds and reduce waste simultaneously. This approach holds the potential for substantial economic gains and addresses waste management challenges inherent in the crustacean industry. Conventionally, crustacean wastes produce bioactive ingredients through extensive chemical procedures. However, these methods have several drawbacks, including excessive water usage and the generation of toxic chemical waste (Tan et al., 2022).

Consequently, there is a need for alternative methods with minimal environmental impact to process crustacean wastes into high-value products efficiently. In a study by Aneesh et al. 2020, processing shrimp waste shells yielded economically valuable bio compounds such as astaxanthin, protein, chitin, and chitosan. Table 1 summarizes several studies that focused on the lab-scale processing of crustacean waste using more environmentally friendly methods than conventional ones.

The referenced journals suggest that the outcomes of these studies hold potential for large-scale production. Moreover, the economic impact of valorizing marine waste lies in the potential for new industries, job creation, and market expansion through the development of sustainable products. Furthermore, this approach aligns with Sustainable Development Goals (SDGs) by promoting responsible consumption and production, addressing marine pollution, and supporting the sustainable use of ocean resources, contributing to economic growth and environmental sustainability. Therefore, this study provides a comparative overview of bioactive components, their potential extraction methods for large-scale production, and their implications within the circular economy and Sustainable Development Goals (SDGs).

Table: Shrimp Shell Wastes Processing Methods to Produce Various Biocompound

Waste Source	Methods	Product	Yield	Potential Advantages	Source
<i>Litopenaeus vannamei</i>	Chemical methods using HCl and NaOH	Chitin Chitosan	-	The modified approach has potential for large-scale production due to its low ash and protein content. This would lead to minimizing the use of chemicals.	Trung et al., 2020
<i>Marsupenaeus japonicas</i>	DES Solvent using choline chloride-malic acid	Chitin	19.41 ± 1.35%	Sustainable, nontoxic, and biodegradable solvents. The chitin films are similar to standard chitin film that can be used as wound healing resources	Saravana et al., 2018 ;
<i>Chionoecetes opilio</i> (snow crab)	Introduced <i>N</i> -acetyl-D-glucosamine into the NADESs	Chitin	85.6%	Eco-friendly, high yield and molecular weight of chitin.	Wang et al., 2022
<i>Solenocera choprai</i> (ridgeback shrimp)	Supercritical CO ₂ extraction Mechanical pressing Chemical Methods	Astaxanthin Protein Chitin Chitosan	0.06 mg/kg dry shell weight 102.10 ± 0.56 g/kg dry weight 224.36 ± 0.32 g/kg dry shell weight 156.99 ± 0.16 g/kg dry shell weight	Shrimp processing discards are the cheapest and best source of good quality astaxanthin for antioxidant and natural colorant in food formulation. It can also be used as a source of protein, chitin, and chitosan for feedstock in biorefinery process	Aneesh et al., 2020
<i>Litopenaeus vannamei</i>	Biological methods using two recombinant aspartic proteases and recombinant chitinase	Protein hydrolysate Chitin Oligomers Astaxanthin Mineral residues	0.45 g/ g shrimp shell 0.17 g/ g shrimp shell 101.3 ug/ g shrimp shell 0.33 g/ g shrimp shell	Elimination of corrosive reagents, zero-waste utilization of shrimp shell, recovery of all shell components and preservation of their natural bioactivities	Deng et al., 2020

Potential Economic Value of Biomaterials from Marine Waste

Shrimp shells comprise α -chitin ranging from 15% to 40%, proteins from 20% to 40%, CaCO₃ 20% to 50% of the shell composition, and minor components such as pigments and metal salts (Kurita, 2006). Chitin is hydrophobic and often transformed into carboxymethyl chitosan for oral delivery of paclitaxel (Azelee et al., 2023; Hosseini et al., 2022). Chitosan is a group of polymers derived through the deacetylation of chitin (Younes & Rinaudo, 2015). Chitosan is used to prepare beads, microcapsules, microspheres, and nanoparticles for use in sustainable release drug delivery systems. Chitin and chitosan derivatives are applicable in biomedicine due to their biocompatible and non-toxic nature. These derivatives can be obtained in various forms, such as hydrogels, scaffolds, and sponges (Ormanci et al., 2019). Astaxanthin, identified chemically as 3,3'-dihydroxy- β , β' -carotene-4,4'-dione, is one of the significant carotenoid pigments found in the byproducts of shrimp processing. Astaxanthin is a preferred choice in various industries, including aquaculture, feed, food, nutraceuticals, pharmaceuticals, and cosmetics, because of its antioxidant properties (Ambati et al., 2014). Figure 1 summarizes the comprehensive applications of crustaceans byproducts in various fields.

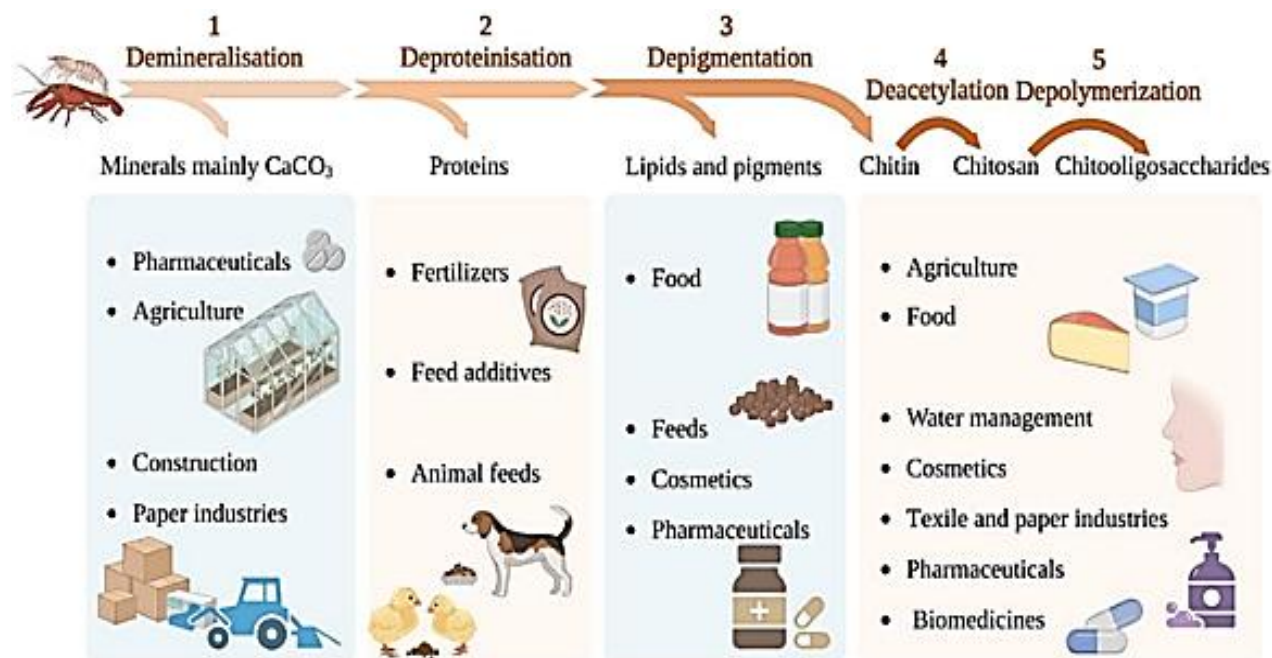


Figure 1. The comprehensive applications of crustaceans byproducts in various fields (Zhang et al., 2023)

Chitin Extraction from Shrimp Shells

Chitin is the most abundant polysaccharide that can be extracted from marine sources such as crustaceans (Coltelli et al., 2022). The extraction process involves demineralization, deproteinization, and decolourization to eliminate proteins, minerals, lipids, and pigments. Grinding for enhancing solution exposure and a few post-treatments like purification techniques may be added to increase the quality of the final product (Pakizeh et al., 2021). Conventionally, chitin and chitosan are extracted using chemical methods. However, using strong acids or bases in conventional methods can harm the physicochemical characteristics of chitin and result in a chemical-containing effluent discharge (Tan et al., 2022). The challenge of insufficient chemical treatments has led to several research utilizing microorganisms and enzymes to extract chitin and chitosan from marine waste. Doan et al. (Doan et al., 2019) reported that fermenting shrimp waste to extract chitin using *B. parables* TKU046 resulted in high deproteinization rates. Deng et al. (Deng et al., 2020) used two recombinant aspartic proteases for protein hydrolysis and recombinant chitinase for chitin hydrolysis. The recovery rate of chitin is 88.9%.

This enzymatic process catalyzes sustainable development, establishing a circular economy within the shrimp processing industry. This innovative approach delivers economic advantages and contributes significantly to environmental well-being (Deng et al., 2020). On the other hand, chitin extraction using sustainable, non-toxic, and biodegradable deep eutectic solvents (DES) can also serve as an alternative. Natural deep eutectic solvents (NADES) are a derivative of deep eutectic solvents (DES), characterized as natural due to their composition derived from primary metabolite groups essential for plant survival. These constituents include sugars, organic acids, bases, and amino acids, mirroring the naturally occurring compounds utilized by plants in their biological processes. (Dai et al., 2013). The NADES-based extraction method demonstrated efficient and eco-friendly chitin extraction from shrimp shells, resulting in high minerals and protein removal from the shells. Characterization results confirmed the superior quality of the extracted chitin (Huang et al., 2018). Moreover, NADES solvent can be recycled. Wang et al. (Wang et al., 2022) reported that the purity of chitin could still reach 80.4% after five cycles of NADES solvent.

Circular Economy

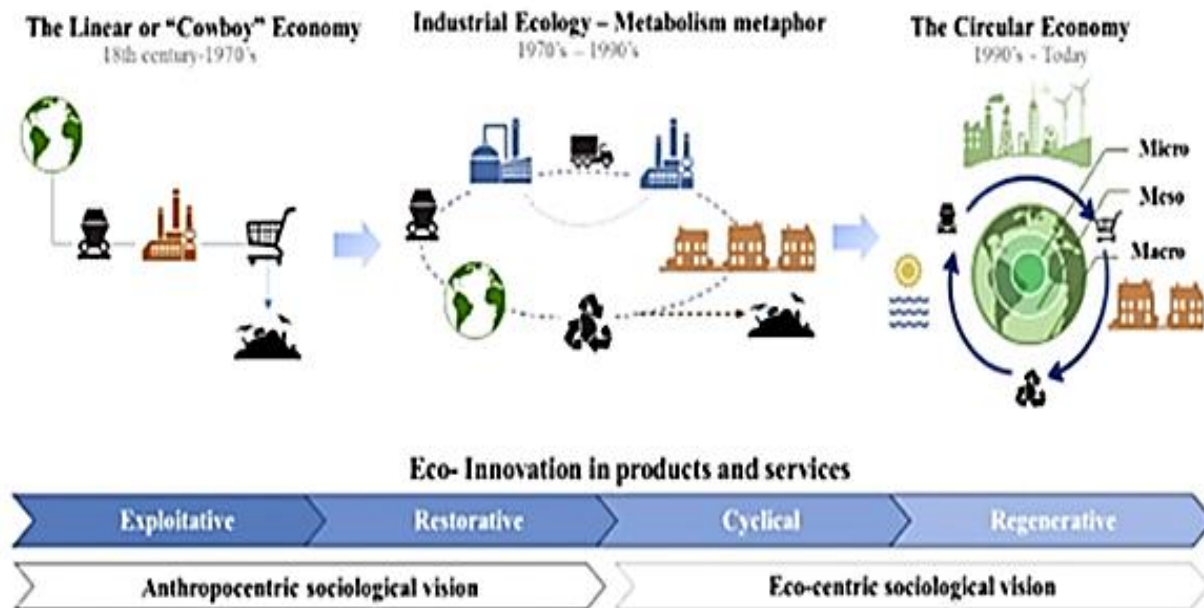
The Circular Economy aims to reduce the underutilization of processing byproducts, increase reuse rates of wasted opportunities, and reduce pressure on natural systems and resources. From a circular business economic model perspective, the goal is to use these waste or byproducts to produce more excellent output value and mitigate their environmental impact, which extends to various sectors (Cooney et al., 2023). The central theme of the CE concept is the valuation of materials in a closed system to enable the use of natural resources while reducing pollution, avoiding resource constraints, and maintaining economic growth (Winans et al., 2017). This idea of material cycles has existed since the dawn of industrialization; we argue that it reduces negative environmental impacts and stimulates new business opportunities. The circular economy is often recommended as an approach to economic growth that aligns with the principles of developing a sustainable economic environment (Korhonen et al., 2018). The circular economy can help transition and change to cleaner and sustainable production and reach a profitable circular state. (van Loon et al., 2020). Unlike the traditional recycling we are used to, practical policies and a business-oriented circular economy approach emphasize the reuse of the products, components and materials, remanufacturing repair, cascading and upgrading, as well as the utilization of wind, biomass, solar and waste-derived energy utilization throughout the product value chain and cradle-to-cradle, also life cycle (Korhonen et al., 2018).

The selected definitions were taken from authoritative sources on CE, such as official (governments, parliaments, or independent public) institutions and nonofficial (nongovernmental, nonprofit, etc.) organizations and associations. Environmental awareness, which includes the understanding, attitudes, and values associated with ecological issues, motivates individuals to engage in environmentally friendly practices and preferences. Even so, more knowledge remains a significant obstacle to comprehending environmental challenges and selecting sustainable alternatives, such as eco-conscious travel. Education is vital in bridging this knowledge gap, as evidenced by prior studies. Notably, no substantial differences in attitudes towards eco-friendly products were observed among different nationalities, likely attributable to the participants' habitual use. These results are consistent with the tenets of a circular economy, which prioritizes education, sustainable consumption, and waste minimization to foster environmentally responsible behaviours (Mazhenova et al., 2016). As a document of legislative proposals for action plans on matters such as raw materials and wastes, no clear definition of CE was proposed in this report. Most of the discourse was on the benefits generated from the transition to CE, including economic gains, energy savings, environmental benefits, local jobs, and opportunities for social integration.

In other EU official documents, some "practical" definitions of CE were provided, including the one used in the EU parliament publications stating that CE is "a production and consumption model which involves reusing, repairing, refurbishing and recycling existing materials and products to keep materials within the economy. Getting hold of the circular economy concept wherever possible will make waste a resource, consequently minimizing waste. It is generally opposed to a traditional, linear economic model, which is based on a 'take-make-consume-throw away' pattern" [44,45]. Since 2015, the U.S. Chamber of Commerce Foundation is focusing its Sustainability Forum on the concept of CE to explore "the powerful impact of the circular economy. How to make the circular economy work for businesses, examine how innovative business models can accelerate cost savings, and explore new advances in cradle-to-cradle design." In the 2015 forum entitled *The Circular Economy: Unleashing New Business Value*, CE was defined as "a model that focuses on careful management of material flows through product design, reverse logistics, business model innovation, and cross-sector collaboration" [46]. Since 2017, the organizers changed the title of their annual event from Sustainability Forum to Sustainability and Circular Economy Summit [47], which echoes the growing interest in CE in the United States. In the report *"Toward the Circular Economy and Business Rationale for an Accelerated Transition"*, the Ellen MacArthur Foundation proposed the following definition of CE: "an industrial system that is restorative or regenerative by intention and design.

It replaces the end-of-life concept with restoration, shifts toward using renewable energy, eliminates toxic chemicals, which impair reuse, and aims to eliminate waste through the superior design of materials, products, systems and business models" [34]. In a report published in 2014, the World Economic Forum used this definition developed by EMF [33]. Circular Economy European Summit is an annual gathering of

scientists, industry experts, and professionals from different backgrounds to debate the global challenges related to sustainability and CE's role in addressing those global challenges. The first congress was held in Barcelona in 2016. The organizers of this summit are defining CE as a "conceptual framework of sustainable development. Its goal is the production of goods and services while at the same time reducing the consumption and wastage of raw materials, water and energy sources" [48]. The Finnish Innovation Fund Sitra is an independent public foundation that promotes sustainability in Finland and worldwide. One of its pioneering efforts related to CE is the organization of the first-ever World Circular Economy Forum in Helsinki in June 2017. In one of its publications, Sitra stated that CE "is based on the sustainable use of resources. This means monitoring, minimizing and eliminating waste flows by circulating, rather than just



consuming, materials. In practice, this could mean not adding substances to raw materials that could harm a process.

Figure 2. Circular economy frame

The government advocates for sustainable production and consumption by fostering green supply chains, assisting small and medium-sized enterprises (SMEs), and promoting environmental sectors like waste recycling. Socially sustainable supply chains increase employee engagement, productivity, and substantial community support. By integrating environmental and social objectives with economic aims, organizations can improve health, safety, and ethical standards throughout their supply chains. Companies need to engage key stakeholders in pertinent initiatives to realize these objectives. In alignment with the Sustainable Development Goals (SDGs), businesses must ensure responsible consumption and production SDG number 12 while safeguarding aquatic ecosystems and SDG number 14 (Duong, 2022).

Sustainable Development Goals

Artificial intelligence (AI) has been significant. Sustainable development is defined as the "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition was established in the 1987 United Nations Publication "Our Common Future" and is now widely used to define the modern concept of sustainability (Halkos et al., 2021). Historically, sustainable development (SD) emerged in environmental concerns, as witnessed by the term's first appearance in the World Charter for the Future (Hák et al., 2016). 2015, the United Nations General Assembly (UN) adopted 17 sustainable development goals (SDGs). These goals aim to set attainable targets that can be achieved as a 2030 agenda for sustainable development (Barbier et al., 2017). We need SDG because the triple bottom line (economy, environment, and society) is not currently achieved (Sachs et al., 2015; Crespo et al., 2017).

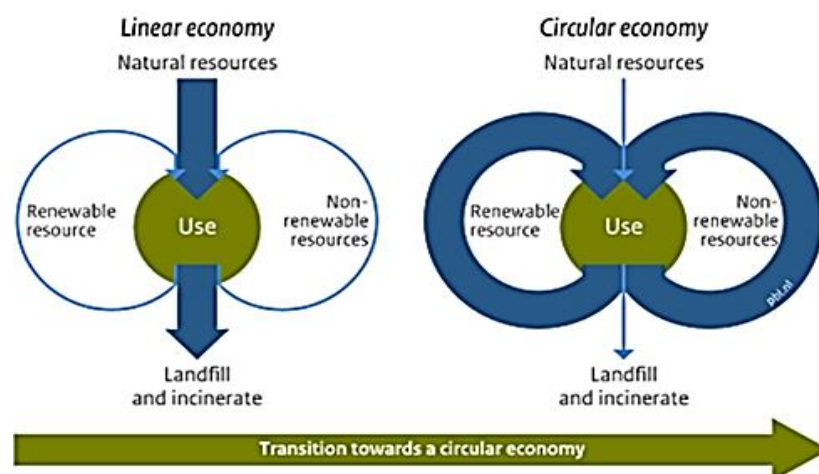


Figure 3. Circular economy frame

METHODOLOGY

The research methodology used is a systematic literature review. The literature that reported experiments on producing bioactive compounds from crustacean waste was sourced from Google Scholar and published in 2018-present. It is viewed as a pathway to sustainable economic development, aligning with building a resilient economic environment. Furthermore, the CE can facilitate the transition towards cleaner and more sustainable production practices, ultimately leading to a profitable circular state. Unlike traditional recycling methods, practical policies and a business-oriented approach to the circular economy emphasize product, component, and material reuse and strategies such as remanufacturing, repair, cascading, and upgrading. Highlight the environmental benefits of shrimp shell waste, such as reducing pollution and waste in the seafood industry, and appeal to environmentally conscious consumers and businesses. Invest in research and development to optimize extraction processes and develop innovative technologies for efficiently utilizing shrimp shell waste. Invest in research and development to identify the cosmetic applications of shrimp shell waste-derived ingredients such as chitin and chitosan. Seven processes are needed to make a Chitin Cleaning and Debris Removal: Drying, Milling, Protein and Mineral Removal, Chitin Extraction, Final Milling, Quality Testing, Packaging and Storage.

RESULTS AND DISCUSSION

Environmental packaging within food delivery systems pertains to consumer attitudes towards sustainable packaging methods. Nonetheless, there are growing concerns regarding the substantial waste produced by these services. Tackling this challenge is consistent with the tenets of the circular economy, which prioritizes the reuse of resources and the reduction of waste. For example, shrimp byproducts, typically considered waste, can be converted into chitin, a valuable substance for creating biodegradable packaging. Integrating such innovations lessens dependence on traditional plastics and redefines waste as a resource, illustrating how circular economy strategies can alleviate environmental repercussions in food delivery systems (Joonho et al., 2024). As we know, Shrimp shells can be repurposed into valuable products such as chitosan and its derivatives, which have applications in drug delivery systems and biomedicine due to their biocompatible and non-toxic nature. Businesses can explore the production of various forms of chitin and chitosan derivatives, including hydrogels, scaffolds, and sponges, to cater to different market needs and applications. Businesses need to integrate waste machine recycling, especially for dryer machines, to adopt sustainable manufacturing practices to minimize waste generation and energy consumption in extracting and processing chitin and chitosan from shrimp shells. Businesses must invest in research and development to explore new applications and improve the efficiency of extracting and processing chitin and chitosan derivatives from shrimp shells.

Shrimp shell waste is to be made into bioplastic that is environmentally friendly and safe to use. Instead of discarding these shells as waste, extracting valuable components like chitin and proteins presents an opportunity to create value-added products with various applications. However, from all theories and results, we found the key to solving this problem is maintaining environmental sustainability management to supply waste and trying not to make new waste when reproducing waste by utilizing waste materials by repurposing shrimp shells into products like chitin and chitosan derivatives as a chemical powder that safe to touch or eaten by human; businesses can contribute to reducing waste sent to landfills and mitigating the environmental burden associated with waste disposal. Ecopreneurship, a fusion of "ecology" and "entrepreneurship," pertains to pioneering enterprises prioritizing environmentally sustainable products and services, frequently referred to as green entrepreneurship or entrepreneurship. Effective waste management poses a significant challenge in urban settings with high population density.

Entrepreneurs can be classified into three distinct categories: those motivated by economic interests (generating value for business proprietors), social interests (enhancing community welfare), or ecological interests (focusing on environmental restoration). Waste reduction can be facilitated through recycling, which converts discarded materials into new products, or by reusing materials directly without additional processing (QA, 2015). This requires investment in R&D, collaboration with academic institutions, and a culture of continuous improvement within businesses. We need help from the chemical laboratory to manage this operational step to reproduce new products like make-up with chitin powder, for example. The enhancement of food byproducts involves a research area where protein extraction occurs post-processing. Proteins are extracted using conventional methods that employ harmful solvents, saturated salts, gel, and ion-exchange chromatography. These methods face various limitations, including low scalability, high expenses, low purification yields, and, often, loss of bioactivity. Consequently, there is a need for innovative, eco-friendly approaches.

CONCLUSION

In conclusion, the discussion about utilizing waste materials like shrimp shells highlights the potential for businesses to create value and contribute to environmental sustainability. While significant opportunities exist in waste materials, businesses face various challenges. These include technological limitations, regulatory compliance, market acceptance, and cost-effectiveness. Overcoming these challenges requires strategic planning, investment, and collaboration across stakeholders. By effectively managing waste integration initiatives, businesses can generate additional revenue, enhance sustainability, and create long-term value for stakeholders. It introduces a systematic framework to help operators identify strategies for valorization based on volume and value considerations. Incheon was selected as the study context due to its leadership in waste reduction, exemplified by its "Comprehensive Plan for Reducing Waste." The city has integrated circular economy principles into its waste management policies, aligning with efforts to build a zero-waste society. The Republic of Korea's Framework Act on Resources Circulation further supports this shift from waste treatment to resource circulation, emphasizing action plans for waste reduction at the metropolitan level. Effective management of food waste, as seen in businesses like Cleame, which utilizes microorganisms in food waste processing, underscores the importance of governmental support and legislation. The findings highlight the significant environmental impact of waste and disposable materials, drawing attention to behavioural and policy interventions for sustainable practices (Junsuk Choi et al., 2024).

Opportunities for valorization or reuse are highlighted to mitigate environmental impact and prevent the loss of valuable resources such as nutrients, energy, and biomass. To elaborate on the sustainability aspect and apply this theory to the circular business model for shrimp waste, it is imperative to emphasize the importance of education and communication strategies. This includes demonstrating the potential for cost savings, revenue generation, and environmental impact reduction associated with circular approaches. Furthermore, building a Triple Helix ecosystem tailored explicitly to the shrimp industry involves fostering collaboration and knowledge exchange. For managerial implication in strategic planning, managers must incorporate waste utilization into their strategic planning process. This involves identifying opportunities for waste utilization, assessing market demand for derived products, and setting clear objectives and targets for waste management

and value creation. Allocating resources is the primary key to managing waste. It makes finding waste in the beach area easier, including finances, workforce, and technology; waste utilization initiatives are crucial. Managers should prioritize investments in research and development, infrastructure, and talent development to support waste integration efforts effectively. Effective supply chain management is essential for integrating waste utilization into business operations. This includes establishing partnerships with suppliers to ensure a consistent supply of raw materials (e.g., shrimp shells), optimizing waste collection and processing logistics, and coordinating with downstream partners for product distribution. As valorized seafood byproducts progress into higher value tiers of the valorization framework, such as food and biopharmaceuticals, it will be essential to establish the quantities and quality of available byproducts. Eco-efficiency and eco-design principles must be integrated to ensure the sustainable development of seafood byproduct valorization.

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