

Strengthening Chitin And Chitosan Downstreaming To Enhance Indonesia Fisheries Export Competitiveness

Agustina Pujiastuti

kementerian kelautan perikanan

*Corresponding Author

Email: ninadkp@gmail.com

Abstract

Indonesia has substantial potential to develop a downstream chitin and chitosan industry because shrimp-processing activities generate shell by-products that can be converted into higher-value biomaterials. However, the utilization of these by-products for industrial chitin and chitosan remains constrained by fragmented raw-material supply, limited commercialization of research and technology, inadequate standardization and quality assurance, limited industrial capacity, and weak institutional coordination. This study aims to assess the current status of downstream chitin and chitosan development in Indonesia, identify the structural factors constraining value-chain development, analyze policy gaps, and formulate a phased policy roadmap. A qualitative descriptive approach was applied using secondary data from regulations, policy documents, official statistics, scientific publications, and institutional reports. The analysis consisted of current-status assessment, root-cause analysis, problem prioritization, policy-gap analysis, policy-alternative assessment, and roadmap formulation. The findings indicate that the principal constraint is not the availability of shrimp-shell resources but the weak integration of the downstream value chain. A four-phase roadmap is proposed covering governance and value-chain integration, industrial development and technology commercialization, international competitiveness, and innovation and sustainability. The framework provides a policy basis for increasing value added and strengthening fisheries export competitiveness through circular utilization of fisheries by-products performance.

Keywords: Chitin; Chitosan; Downstream Industry; Fisheries By-Products; Value Addition; Policy Roadmap

INTRODUCTION

The global transition toward bio-based and circular production has increased attention to marine biomass as a source of renewable materials. Chitin and chitosan are among the most important marine-derived biopolymers because of their biodegradability, biocompatibility, and broad applications in food, agriculture, environmental management, biomedical products, packaging, and other industries (Younes & Rinaudo, 2015; Hamed et al., 2016; Santos et al., 2020). Crustacean-processing residues are particularly important because shrimp and other shellfish shells contain substantial amounts of chitin and can be converted into products with higher economic value than untreated by-products (Arbia et al., 2013; Amiri et al., 2022).

The utilization of seafood by-products is also increasingly linked to circular-economy and blue-bioeconomy objectives. Seafood waste valorization can reduce underutilization of biomass while creating additional products and economic opportunities along the value chain (Cooney et al., 2023; Junceda-Mena et al., 2023). Recent research shows that the technological basis for extracting and modifying chitin and chitosan continues to expand, including chemical, biological, enzymatic, and greener extraction approaches. Nevertheless, industrial scale-up, consistency of product characteristics, and commercialization remain important challenges (Hosney et al., 2022; Sixto-Berrocal et al., 2023; Gao et al., 2024).

Indonesia has a strategic opportunity to develop this value chain because fisheries and aquaculture generate substantial volumes of aquatic products and processing activities. Official fisheries statistics provide evidence of the scale and diversity of Indonesia's fisheries sector and its production and trade activities (Ministry of Marine Affairs and Fisheries, 2024). At the international level, FAO emphasizes the upgrading of aquatic value chains and the sustainable utilization of aquatic resources as part of Blue Transformation (Food and Agriculture

Organization, 2024). For Indonesia, therefore, downstream utilization of processing by-products can complement broader fisheries industrialization and sustainable resource-utilization objectives.

However, the existence of raw-material potential does not automatically result in a competitive downstream industry. Research on crustacean by-products indicates that the transition from waste to commercial products requires technological capability, appropriate processing systems, market development, quality control, and value-chain coordination (Hamed et al., 2016; Amiri et al., 2022). The marine chitin/chitosan value chain also remains characterized by a gap between research activities and market-oriented industrial applications (Vieira et al., 2023). Environmental and energy considerations further indicate that the choice of extraction and conversion technologies affects the sustainability and feasibility of industrial production (Vicente et al., 2024).

In the Indonesian context, the policy challenge is consequently broader than technology availability. It concerns the connection between raw-material collection, research commercialization, industrial investment, product standards, quality assurance, market access, and institutional coordination. The national planning framework for 2025–2029 places industrial development, value creation, and cross-sectoral policy coordination within the national development agenda (Government of Indonesia, 2025). This context creates a need to assess whether the existing policy and institutional framework is sufficiently connected to the specific requirements of a chitin and chitosan value chain.

Despite these opportunities, Indonesia's downstream development of chitin and chitosan remains relatively underdeveloped. Most shrimp shell waste is still utilized for low-value products, animal feed ingredients, compost, or disposed of without further processing. Industrial production capacity remains limited and has not yet matched the availability of domestic raw materials or growing international demand. Consequently, Indonesia has not fully optimized its comparative advantage to develop a competitive chitin and chitosan industry capable of generating higher value-added exports (Badan Pusat Statistik, 2024; Ministry of Industry, 2023; Ministry of Marine Affairs and Fisheries, 2024).

Several interrelated structural constraints contribute to this condition. The supply chain for shrimp shell waste remains fragmented due to the geographical dispersion of seafood processing industries and limited integration between raw material suppliers and downstream manufacturers. Although research institutions have developed various extraction technologies, commercialization and industrial adoption remain limited. Furthermore, investment in downstream processing industries is still relatively low, while product standardization, certification systems, and international quality assurance have not been fully implemented. Institutional responsibilities are distributed among several ministries and agencies, often resulting in fragmented governance and limited policy coordination. These challenges reduce industrial competitiveness and constrain the development of export-oriented chitin and chitosan industries (OECD, 2023; Ministry of Industry, 2023; Ministry of Marine Affairs and Fisheries, 2024).

Although previous studies have extensively investigated extraction technologies, physicochemical properties, biomedical applications, and environmental benefits of chitin and chitosan, relatively limited attention has been paid to the institutional and policy dimensions required to strengthen downstream industrial development, particularly in Indonesia. Most existing studies primarily emphasize technological innovation and product applications, whereas the integration of supply chain management, industrial policy, research commercialization, investment promotion, product standardization, and institutional coordination has received considerably less attention. Consequently, comprehensive policy strategies capable of transforming Indonesia's abundant shrimp shell resources into a competitive downstream

industry remain insufficiently explored (Ahmed et al., 2022; Arbia et al., 2023; Kumar et al., 2023).

Previous studies have largely emphasized extraction methods, physicochemical characteristics, applications, and environmental or technical aspects of chitin and chitosan (Younes & Rinaudo, 2015; Santos et al., 2020; Gao et al., 2024). Although recent literature has increasingly discussed valorization and value chains, there remains limited policy-oriented analysis that integrates raw-material supply, research commercialization, industrial development, standardization, and institutional coordination specifically for Indonesia (Junceda-Mena et al., 2023; Vieira et al., 2023). This study addresses that gap by examining downstream development from an integrated policy and value-chain perspective.

Accordingly, this study asks: how can Indonesia strengthen downstream chitin and chitosan development so that fisheries by-products generate greater value added and contribute to export competitiveness? The study aims to (1) assess the current status of downstream chitin and chitosan development; (2) identify the main structural root causes; (3) analyze gaps between the existing policy framework and the requirements of an integrated value chain; and (4) formulate a phased policy roadmap. The contribution of the study lies in linking technological and resource potential with institutional, industrial, and market dimensions within one policy-oriented analytical framework.

RESEARCH METHODS

This study employed a qualitative descriptive approach to examine the current condition and policy challenges of downstream chitin and chitosan development in Indonesia. Qualitative description is appropriate when the objective is to provide a comprehensive account of a phenomenon while remaining close to the data and events being described (Sandelowski, 2000). The approach was therefore used to organize evidence on raw-material availability, industrial development, value-chain integration, technology and innovation, standardization, market access, and policy support before drawing policy implications.

The study utilized secondary data obtained from government regulations and policy documents, official statistics, scientific publications, institutional reports, and relevant industry information. The data were analyzed through several sequential stages: (1) current status analysis, (2) root cause analysis, (3) problem prioritization using the Urgency, Seriousness, and Growth (USG) method, (4) policy gap analysis, (5) policy alternative assessment, and (6) policy roadmap formulation. The study used secondary data obtained from Indonesian regulations and policy documents, official fisheries statistics, international institutional reports, scientific publications, and other relevant institutional sources. The analytical procedure consisted of six sequential stages: (1) current-status assessment; (2) root-cause analysis; (3) problem prioritization using the Urgency, Seriousness, and Growth (USG) framework; (4) policy-gap analysis; (5) policy-alternative assessment; and (6) formulation of a phased policy roadmap. The USG stage was used as a structured screening device to distinguish problems requiring greater policy attention; numerical scores should be reported only when the underlying scoring matrix is available.

Current-status assessment was used to describe the condition of the chitin and chitosan value chain, including raw materials, processing, industrial capacity, technology, standards, and markets. Root-cause analysis was then used to organize the structural factors underlying the identified constraints. Policy-gap analysis compared the existing regulatory and institutional framework with the conditions required for an integrated chitin and chitosan value chain. Policy alternatives were assessed using effectiveness, efficiency, feasibility, and long-term impact as decision criteria. The final stage translated the preferred policy direction into a phased roadmap.

For the competitiveness dimension, the analysis draws on the principle that national competitive advantage is shaped not only by natural resource endowments but also by the capacity to organize production, innovation, supporting industries, and market-oriented capabilities (Porter, 1990). The policy analysis therefore treats raw-material availability as an enabling condition rather than as sufficient evidence of downstream competitiveness.

RESULTS AND DISCUSSION

Results

Current Status of Indonesia's Chitin and Chitosan Industry

Indonesia has a substantial resource base for developing chitin and chitosan because shrimp-processing activities generate shell by-products containing chitin and other valuable components. The fisheries sector itself has a broad production and trade base, while FAO identifies value-chain upgrading and sustainable utilization of aquatic resources as important elements of Blue Transformation (Food and Agriculture Organization, 2024; Ministry of Marine Affairs and Fisheries, 2024). Scientific reviews further establish crustacean shells as an important feedstock for chitin and chitosan production (Arbia et al., 2013; Santos et al., 2020).

Despite this resource potential, the downstream value chain remains less developed than the potential of the raw-material base would suggest. The literature identifies persistent challenges in processing scale-up, commercialization, product consistency, and industrial application. In particular, chitosan valorization has progressed more rapidly in scientific literature than in commercially established applications (Junceda-Mena et al., 2023; Vieira et al., 2023). Recent reviews also indicate that industrial scale-up remains constrained by process complexity and the need to control product characteristics according to application requirements (Hosney et al., 2022; Gao et al., 2024).

The current-status assessment consequently identifies five interconnected dimensions of constraint: fragmented raw-material supply, limited commercialization of research and technology, limited industrial investment and processing capacity, incomplete standardization and quality assurance, and fragmented institutional coordination. These constraints affect the ability to transform shrimp-processing by-products into consistent, marketable, and export-oriented chitin and chitosan products.

Root Causes of the Problem

The root-cause analysis identifies five major structural causes. First, raw-material supply is fragmented because processing activities and potential suppliers are dispersed, making aggregation, quality control, and continuous supply more difficult. Second, research outputs do not automatically translate into industrial adoption because laboratory-scale performance does not guarantee commercial feasibility. Third, downstream investment and processing capacity require capital, technology, infrastructure, and market certainty. Fourth, product standardization and quality assurance are essential because chitin and chitosan properties vary according to feedstock and processing conditions. Fifth, responsibilities for fisheries, industry, research, standards, investment, and trade are distributed across institutions, creating a need for stronger coordination.

Table 1. Root Cause Analysis Matrix

Root Cause	Observed constraint	Effect on value chain
Fragmented supply chain	Irregular aggregation and quality of shrimp-shell by-products	Uncertain feedstock availability and higher transaction costs

Weak research commercialization	Limited transition from laboratory results to industrial adoption	Slow technology diffusion and product development
Limited industrial investment	Small processing capacity and limited scale-up	Low ability to meet consistent market demand
Incomplete standardization and quality assurance	Variation in product characteristics and certification readiness	Restricted access to higher-value and export markets
Fragmented institutional coordination	Policies and programs are distributed across institutions	Weak policy coherence across the value chain

Policy Gap Analysis

Indonesia already has a national planning framework and fisheries-sector policies that support industrial development, value addition, and sustainable utilization of marine resources. The current national medium-term development plan for 2025–2029 provides the overarching planning framework, while fisheries-sector statistics and programs provide sectoral evidence and implementation instruments (Government of Indonesia, 2025; Ministry of Marine Affairs and Fisheries, 2024). The policy gap identified in this study is therefore not the complete absence of policy, but the limited integration of existing instruments around the specific requirements of the chitin and chitosan value chain.

The main gaps are: (1) limited integration of raw-material management with downstream industrial planning; (2) insufficient mechanisms linking research outputs with industrial commercialization; (3) limited alignment between investment facilitation and technology scale-up; (4) incomplete product standardization and quality-assurance pathways for differentiated applications; and (5) limited cross-institutional coordination covering fisheries, industry, research, standards, investment, and trade. These gaps are consistent with the broader policy literature emphasizing coordinated governance, innovation, and participation in global value chains as foundations for a productive and sustainable ocean economy (OECD, 2025; United Nations Industrial Development Organization, 2024).

Proposed Policy Roadmap

Based on the current status, root cause, and policy gap analyses, this study formulates a four-phase policy roadmap for strengthening Indonesia's chitin and chitosan downstream industry. The first phase focuses on governance strengthening through regulatory harmonization, institutional coordination, development of a national database, and standardized raw-material management. The second phase focuses on industrial development through technology commercialization, investment facilitation, industrial clustering, and expansion of processing capacity. The third phase emphasizes international competitiveness through improved quality assurance, product certification, export promotion, and market diversification. The fourth phase focuses on innovation and sustainability through advanced research, product diversification, circular economy implementation, and continuous industrial upgrading. Based on the current-status, root-cause, and policy-gap analyses, a four-phase roadmap is proposed. Phase 1 focuses on governance and value-chain integration through regulatory alignment, institutional coordination, raw-material mapping, and development of a reliable database. Phase 2 focuses on industrial development through technology commercialization, investment facilitation, industrial clustering, and expansion of processing capacity. Phase 3 focuses on international competitiveness through product standardization, quality assurance, certification, market development, and export promotion. Phase 4 focuses on innovation and sustainability through

advanced research, product diversification, green processing, circular-economy practices, and continuous industrial upgrading.

The roadmap is intentionally sequential. Governance and data are positioned as enabling foundations; industrial scale-up follows once supply and institutional arrangements are strengthened; international market development follows improvements in product consistency and quality assurance; and advanced innovation is positioned as a mechanism for continuous upgrading. This sequencing is consistent with the literature on seafood by-product valorization, which emphasizes coordination among producers, processors, regulators, investors, and knowledge institutions to move from waste management toward economically viable circular production (Cooney et al., 2023; Vieira et al., 2023).

discussion

The findings indicate that Indonesia's principal challenge is not simply the availability of shrimp-shell biomass but the ability to organize that biomass into an integrated industrial value chain. The literature similarly shows that the commercial potential of chitin and chitosan depends on the interaction between feedstock quality, processing technology, product specifications, market applications, and industrial scale-up (Hamed et al., 2016; Amiri et al., 2022; Gao et al., 2024). Thus, a downstream strategy based solely on increasing extraction capacity would not address the full set of structural constraints identified in this study.

The commercialization gap is particularly important. Research on extraction technologies continues to expand, including biological and greener approaches, but the existence of technically feasible processes does not guarantee industrial adoption. Industrialization requires process reliability, economic feasibility, product consistency, infrastructure, investment, and a defined market application (Arbia et al., 2013; Sixto-Berrocal et al., 2023; Vicente et al., 2024). This explains why research commercialization is treated as a separate root cause rather than being subsumed under technology availability.

The standardization issue is equally important for export competitiveness. Chitin and chitosan are not single uniform commodities; their characteristics depend on source material and processing conditions and must be matched to the intended application (Younes & Rinaudo, 2015; Santos et al., 2020). Consequently, quality assurance and certification should be connected to product differentiation and market requirements rather than treated only as administrative compliance. This is particularly relevant for a strategy that seeks to move from commodity-oriented fisheries exports toward higher-value intermediate biomaterials.

The policy-gap findings also suggest that coordination is a central implementation issue. The national development framework provides an enabling policy environment, but a specific value chain that crosses fisheries, industrial processing, research, standards, investment, and trade requires coordination mechanisms that connect these policy domains. OECD and UNIDO emphasize governance, innovation, technology absorption, and integration into value chains as important conditions for sustainable industrial development (OECD, 2025; United Nations Industrial Development Organization, 2024). The implication for Indonesia is that downstream chitin and chitosan development should be treated as an intersectoral industrial-policy issue rather than as a narrow fisheries-processing program.

The proposed four-phase roadmap responds to these structural conditions. The first phase reduces coordination and information constraints; the second creates the industrial capability required for scale; the third improves the ability to compete in higher-value markets; and the fourth supports continuous upgrading and environmental sustainability. The approach is consistent with the circular-economy literature, which emphasizes that seafood by-product valorization requires coordinated supply chains and economically viable pathways rather than isolated waste-processing technologies (Cooney et al., 2023; Junceda-Mena et al., 2023).

The policy contribution of this study is therefore the integration of resource potential, technology commercialization, industrial development, standardization, and governance within

one analytical framework. Rather than assuming that abundant shrimp-shell resources will automatically create competitive advantage, the framework treats resources as an input that must be converted through coordinated capabilities and institutions. This interpretation is consistent with the broader competitiveness perspective that sustainable national advantage depends on the organization of productive capabilities and supporting systems, not only on natural-resource endowments (Porter, 1990)

CONCLUSION

Indonesia has a strong basis for developing a downstream chitin and chitosan industry from fisheries by-products. However, the findings show that the main constraint is not raw-material potential but weaknesses in the integration of the downstream value chain. Five structural constraints were identified: fragmented raw-material supply, limited commercialization of research and technology, limited industrial investment and capacity, incomplete standardization and quality assurance, and fragmented institutional coordination.

The policy-gap analysis indicates that Indonesia already has relevant national planning and fisheries-sector policy instruments, but these instruments are not yet sufficiently connected to the specific requirements of the chitin and chitosan value chain. The study therefore proposes a four-phase roadmap consisting of governance and value-chain integration, industrial development and technology commercialization, international competitiveness, and innovation and sustainability. The roadmap is expected to provide a practical policy framework for transforming fisheries by-products into higher-value biomaterials, strengthening circular utilization, and improving the competitiveness of Indonesian fisheries exports.

A limitation of the study is its reliance on secondary data and qualitative policy analysis. The roadmap should therefore be complemented by firm-level feasibility studies, detailed supply-chain mapping, techno-economic assessment, market-demand analysis, and quantitative baseline indicators before implementation. Future research should also assess specific industrial clusters and compare the competitiveness of Indonesian chitin and chitosan products across target export markets

REFERENCES

- Amiri, H., Aghbashlo, M., Sharma, M., Gaffey, J., Manning, L., Moosavi Basri, S. M., Kennedy, J. F., Gupta, V. K., & Tabatabaei, M. (2022). Chitin and chitosan derived from crustacean waste valorization streams can support food systems and the UN Sustainable Development Goals. *Nature Food*, 3, 822–828. <https://doi.org/10.1038/s43016-022-00591-y>
- Arbia, W., Arbia, L., Adour, L., & Amrane, A. (2013). Chitin extraction from crustacean shells using biological methods—A review. *Food Technology and Biotechnology*, 51(1), 12–25. <https://hrcak.srce.hr/99743>
- Cooney, R., de Sousa, D. B., Fernández-Ríos, A., Mellett, S., Rowan, N., Morse, A. P., Hayes, M., Laso, J., Regueiro, L., Wan, A. H. L., & Clifford, E. (2023). A circular economy framework for seafood waste valorisation to meet challenges and opportunities for intensive production and sustainability. *Journal of Cleaner Production*, 392, 136283. <https://doi.org/10.1016/j.jclepro.2023.136283>
- Food and Agriculture Organization. (2024). The state of world fisheries and aquaculture 2024: Blue transformation in action. FAO. <https://doi.org/10.4060/cd0683en>

- Gao, M., Tang, H., & Zhu, H. (2024). Advances in extraction, utilization, and development of chitin/chitosan and its derivatives from shrimp shell waste. *Comprehensive Reviews in Food Science and Food Safety*, 23(5), e70008. <https://doi.org/10.1111/1541-4337.70008>
- Government of Indonesia. (2025). Peraturan Presiden Nomor 12 Tahun 2025 tentang Rencana Pembangunan Jangka Menengah Nasional Tahun 2025–2029.
- Hamed, I., Özogul, F., & Regenstien, J. M. (2016). Industrial applications of crustacean by-products (chitin, chitosan, and chitooligosaccharides): A review. *Trends in Food Science & Technology*, 48, 40–50. <https://doi.org/10.1016/j.tifs.2015.11.007>
- Hosney, A., Ullah, S., & Barčauskaitė, K. (2022). A review of the chemical extraction of chitosan from shrimp wastes and prediction of factors affecting chitosan yield by using an artificial neural network. *Marine Drugs*, 20(11), 675. <https://doi.org/10.3390/md20110675>
- Junceda-Mena, I., García-Junceda, E., & Revuelta, J. (2023). From the problem to the solution: Chitosan valorization cycle. *Carbohydrate Polymers*, 309, 120674. <https://doi.org/10.1016/j.carbpol.2023.120674>
- Ministry of Marine Affairs and Fisheries of the Republic of Indonesia. (2024). Kelautan dan perikanan dalam angka 2024. Kementerian Kelautan dan Perikanan.
- OECD. (2025). The ocean economy to 2050. OECD Publishing. <https://doi.org/10.1787/a9096fb1-en>
- Porter, M. E. (1990). The competitive advantage of nations. Free Press.
- Sandelowski, M. (2000). Whatever happened to qualitative description? *Research in Nursing & Health*, 23(4), 334–340. [https://doi.org/10.1002/1098-240X\(200008\)23:4<334::AID-NUR9>3.0.CO;2-G](https://doi.org/10.1002/1098-240X(200008)23:4<334::AID-NUR9>3.0.CO;2-G)
- Santos, V. P., Marques, N. S. S., Maia, P. C. S. V., de Lima, M. A. B., de Oliveira Franco, L., & de Campos-Takaki, G. M. (2020). Seafood waste as attractive source of chitin and chitosan production and their applications. *International Journal of Molecular Sciences*, 21(12), 4290. <https://doi.org/10.3390/ijms21124290>
- Sixto-Berrocal, A. M., Vázquez-Aldana, M., Miranda-Castro, S. P., Martínez-Trujillo, M. A., & Cruz-Díaz, M. R. (2023). Chitin/chitosan extraction from shrimp shell waste by a completely biotechnological process. *International Journal of Biological Macromolecules*, 230, 123204. <https://doi.org/10.1016/j.ijbiomac.2023.123204>
- United Nations Industrial Development Organization. (2024). Industrial development report 2024: Turning challenges into sustainable solutions: The new era of industrial policy. UNIDO.
- Vicente, F. A., Hren, R., Novak, U., Čuček, L., Likozar, B., & Vujanović, A. (2024). Energy demand distribution and environmental impact assessment of chitosan production from shrimp shells. *Renewable and Sustainable Energy Reviews*, 192, 114204. <https://doi.org/10.1016/j.rser.2023.114204>
- Vieira, H., Lestre, G. M., Solstad, R. G., Cabral, A. E., Botelho, A., Helbig, C., Coppola, D., de Pascale, D., Robbins, J., Raes, K., Lian, K., Tsirtsidou, K., Leal, M. C., Scheers, N., Calado, R., Corticeiro, S., Rasche, S., Altintzoglou, T., Zou, Y., & Lillebø, A. I. (2023). Current and expected trends for the marine chitin/chitosan and collagen value chains. *Marine Drugs*, 21(12), 605. <https://doi.org/10.3390/md21120605>
- Yang, Y., Yazdani, L., Aghbashlo, M., Gupta, V. K., Pan, J., Tabatabaei, M., & Rajaei, A. (2023). Product diversification to boost the sustainability of the shrimp processing industry: The case of shrimp-waste driven chitosan-based food Pickering emulsion stabilizers. *Journal of Cleaner Production*, 425, 138958. <https://doi.org/10.1016/j.jclepro.2023.138958>
- Younes, I., & Rinaudo, M. (2015). Chitin and chitosan preparation from marine sources: Structure, properties and applications. *Marine Drugs*, 13(3), 1133–1174. <https://doi.org/10.3390/md13031133>