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Refined Shrimp Peptide Concentrate: Regulatory, Value Chain and Circular Blue Bioeconomy Perspectives

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Abstract

The European Union Regulation (EU) 2015/2283 on novel foods has created new opportunities for the valorization of marine by-products within the framework of the circular bioeconomy and sustainable blue economy. Refined shrimp peptide concentrate (RSPC), obtained through enzymatic hydrolysis of *Pandalus borealis* shells and heads, represents a relevant case study for examining the interaction between food innovation, regulatory assessment, sustainability, and value-chain development. This study analyzes the EFSA scientific opinion on RSPC and reviews available compositional, toxicological, allergenicity, and clinical evidence, contextualizing the ingredient within European policies on circular economy, resource efficiency, and sustainable food systems. The assessment indicates that RSPC consists mainly of 8 low-molecular-weight peptides with demonstrated angiotensin-converting enzyme (ACE) inhibitory activity and potential applications in blood pressure management. Beyond its functional properties, the valorization of shrimp processing by-products offers opportunities to reduce waste generation, increase resource efficiency, and create new economic value within the seafood sector. The case study highlights how the novel food regulatory framework can support the safe market introduction of innovative marine-derived ingredients while contributing to circular economy objectives. Although challenges related to allergenicity management, consumer acceptance, and industrial scalability remain, RSPC demonstrates the potential of marine by-product valorization to foster more sustainable, resilient, and economically viable food systems.



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1. Introduction

Regulation (EU) 2015/2283 on novel foods has redefined the governance of food innovation in the European Union, updating and consolidating the regulatory framework established in 1997 [1]. It introduced a centralized Union list and an EFSA-based safety assessment to ensure that novel foods can be placed on the market while guaranteeing a

high level of consumer protection. Beyond food safety, the Regulation aims to support innovation and improve the functioning of the internal market through harmonized procedures and timelines [1]. Within this framework, marine-derived ingredients obtained from seafood processing by-products represent an emerging category of novel foods where regulatory compliance, technological innovation and resource valorization converge.

At the same time, Regulation (EU) 2015/2283 is increasingly interpreted in light of broader European policy initiatives, including the Farm to Fork Strategy, the Circular Economy Action Plan, the Zero Waste Initiative and the Blue Economy Agenda, which promote more resource-efficient and sustainable food systems [2]. In this context, novel foods may facilitate the development of innovative value chains, provided that their safety and nutritional suitability are scientifically demonstrated.

Among these ingredients, refined shrimp peptide concentrate (RSPC), produced through the enzymatic hydrolysis of *P. borealis* shells and heads, represents a particularly relevant case study. Sustainable food innovation increasingly relies on the diversification of protein sources and the recovery of underutilized biomass, including seafood processing by-products rich in proteins, peptides, lipids, chitin and other bioactive compounds [3,4]. Technologies such as enzymatic hydrolysis, membrane filtration and drying allow these by-products to be converted into high-value functional ingredients with potential applications in food and nutraceutical products [5].

When intended for human consumption in the European Union, these products fall within the scope of Regulation (EU) 2015/2283 and require a comprehensive scientific evaluation by EFSA, as illustrated by the authorization process for Refined Shrimp Peptide Concentrate (RSPC) [6]. Beyond assessing product safety, this regulatory pathway influences the development and market introduction of innovative marine-derived ingredients.

The present review uses RSPC as a regulatory case study to examine the interaction between food safety assessment, shrimp by-product valorization and the development of innovative seafood value chains. Specifically, it analyses the EFSA scientific opinion and the regulatory framework established by Regulation (EU) 2015/2283, discusses the technological and value-chain implications of shrimp by-product valorization, and explores the opportunities and remaining challenges associated with the development of innovative marine-derived functional ingredients.

2. Review Methodology

2.1. Literature Search Strategy

This work was conducted as a narrative review supported by a regulatory case study focusing on Refined Shrimp Peptide Concentrate (RSPC) as an example of marine by-product valorization under the European Novel Food Regulation. Scientific literature was identified through searches in PubMed, Scopus, and Web of Science using combinations of the following keywords: shrimp peptide concentrate, marine bioactive peptides, shrimp by-products, novel food, Regulation (EU) 2015/2283, circular economy, blue economy, seafood waste valorization, enzymatic hydrolysis, and functional foods. The literature search was conducted between January and May 2026 and included publications available up to May 2026. In addition, official documents published by the European Food Safety Authority (EFSA), the European Commission, the U.S. Food and Drug Administration (FDA), the Food and Agriculture Organization of the United Nations (FAO), the Organisation for Economic Co-operation and Development (OECD), and the International Labour Organization (ILO) were consulted to analyse the regulatory, environmental, and socio-economic context.

2.2. Eligibility Criteria

Priority was given to peer-reviewed scientific articles, official regulatory documents, international reports, and policy papers relevant to shrimp by-product valorization, marine-derived bioactive peptides, food safety assessment, and circular bioeconomy strategies. Preference was given to recent publications, while earlier studies were included when considered seminal references for peptide characterization, bioactivity, or regulatory development. The EFSA Scientific Opinion on Refined Shrimp Peptide Concentrate and the corresponding European Commission Implementing Regulation were used as the primary regulatory references for the case study.

2.3. Regulatory Case Study

The EFSA Scientific Opinion on Refined Shrimp Peptide Concentrate (EFSA Journal, 2018) was used as the primary regulatory case study throughout this review. Information regarding the manufacturing process, compositional characteristics, toxicological assessment, allergenicity, nutritional properties, clinical evidence and authorized conditions of use was extracted and critically interpreted within the framework of Regulation (EU) 2015/2283. The EFSA assessment was subsequently integrated with scientific literature and international policy documents (FAO, OECD, European Commission and FDA) to discuss the technological, environmental, economic and regulatory implications of shrimp by-product valorization.

2.4. Scope of the Review

The objective of this review is not to provide a systematic synthesis or quantitative meta-analysis, but rather to critically discuss the available scientific and regulatory evidence concerning Refined Shrimp Peptide Concentrate within the broader framework of sustainable seafood systems. By integrating scientific literature with regulatory and policy documents, the review explores how the authorization of RSPC exemplifies the interaction between food safety assessment, marine by-product valorization, circular economy principles, and sustainable blue economy strategies. Particular attention is devoted to the implications for innovation, resource efficiency, and the development of high-value marine food ingredients. Macroeconomic indicators reported by international organizations (e.g., FAO, OECD, the European Commission, the World Bank and ILO) were included to contextualize the broader policy and economic environment of marine by-product valorization. These indicators should therefore be interpreted as background information and not as quantitative estimates of the specific economic or environmental contribution of Refined Shrimp Peptide Concentrate.

3. Shrimp By-Product Valorization: From Waste to High-Value Marine Ingredients

At the global level, the shrimp processing industry generates substantial quantities of by-products, primarily consisting of shells, heads, and exoskeletal fractions, which can account for approximately 40–60% of the total biomass depending on the species and processing methods [7]. According to the Food and Agriculture Organization (FAO), global crustacean production has exceeded 10 million tonnes annually, with shrimp representing a dominant share of aquaculture and capture fisheries. Based on these estimates, shrimp processing alone is responsible for the generation of several million tonnes of by-products each year, highlighting the scale of this underutilized resource and concerns about their food waste impact on environments [8].

Traditionally, shrimp by-products have been treated as low-value waste and are often disposed of through landfill, incineration, or, in some cases, marine discharge, generating

both environmental pressures and economic costs. The World Bank estimates that global food loss and waste generates economic losses exceeding USD 900 billion annually, with seafood supply chains contributing significantly due to high perishability and processing waste fractions. Disposal costs for seafood by-products can range from 50 to 150 EUR per tonne depending on local regulations and treatment requirements, representing a direct economic burden for processing industries [9].

From an environmental perspective, shrimp processing residues are characterized by a high organic load, including proteins, lipids, and minerals, with biochemical oxygen demand (BOD) values that can exceed 20,000 mg/L in untreated effluents. If not properly managed, these residues may contribute to eutrophication, oxygen depletion, and ecosystem degradation in coastal areas. The decomposition of these organic fractions also generates greenhouse gas emissions, increasing the overall environmental footprint of seafood production systems [10].

The FAO highlights that improving the utilization of fisheries and aquaculture by-products is a key component of the Blue Transformation strategy, promoting a shift from waste disposal to resource recovery throughout aquatic food value chains [10]. Several successful examples demonstrate the feasibility of this transition. Fish skins, scales and bones are increasingly processed into collagen and gelatin for food, cosmetic and biomedical applications; fish frames and viscera are recovered for the production of fishmeal and fish oil used in aquaculture feeds; while crustacean shells, including shrimp by-products, are valorized as sources of chitin, chitosan, carotenoids such as astaxanthin, and bioactive peptides with applications in functional foods, nutraceuticals and pharmaceuticals. These industrial practices illustrate how materials traditionally considered waste can be transformed into high-value bio-based products, simultaneously reducing disposal volumes, improving resource efficiency and generating additional revenue streams for seafood processors. Such examples demonstrate that by-product valorization is not only an environmental strategy but also an economically viable pathway supporting circular bioeconomy and sustainable seafood systems [10].

From an economic standpoint, the disposal of shrimp by-products represents not only a cost but also a loss of valuable biomass rich in functional compounds. Seafood processing by-products are estimated to account for up to 60–70% of total biomass in shellfish processing, highlighting a substantial untapped economic potential [11]. In contrast, valorization pathways can significantly increase the economic value of these materials: chitin, for example, can reach market prices of 10–20 EUR/kg depending on purity and application, while astaxanthin is among the highest-value natural carotenoids, with prices ranging from 2000 to over 7000 EUR/kg in nutraceutical markets.

In response to these challenges, increasing attention has been directed towards the recovery and valorization of shrimp processing side streams within a circular economy framework. Shrimp by-products are a rich source of high-value compounds, including chitin, astaxanthin, and proteins and peptides with functional and bioactive properties [12]. The global chitin and chitosan market is projected to exceed USD 20 billion by 2030, reflecting growing demand across food, pharmaceutical, agricultural, and environmental applications [13].

Technological advances in biorefinery approaches, including enzymatic hydrolysis, fermentation, and membrane separation processes, have enabled the efficient extraction and transformation of these compounds into value-added products [14]. In particular, the production of bioactive peptides through controlled hydrolysis represents a high-value valorization pathway, enabling the conversion of low-value waste into functional ingredients with potential health benefits and market applications in the nutraceutical sector.

This approach aligns with the principles of the blue economy by promoting resource efficiency, reducing environmental burdens associated with waste disposal, and supporting the development of new value chains within the seafood sector. Importantly, this transition reflects a shift from cost-center waste management practices to value-generating processes, with significant implications for economic sustainability, industrial competitiveness, and the resilience of marine-based food systems.

Overall, these advances demonstrate that shrimp processing by-products represent a valuable secondary resource capable of supporting the production of high-value marine ingredients, including bioactive peptides such as RSPC. This transition from waste disposal to resource recovery is summarized in Table 1.

In fact, a comparative overview of conventional disposal and valorization pathways for shrimp by-products is presented in Table 1, highlighting the transition from cost-intensive waste management practices to value-generating circular bioeconomy processes supported by recent advances in seafood by-product valorization [11,12].

Table 1. Economic and environmental comparison between disposal and valorization pathways of shrimp by-products.

Indicator	Conventional Disposal	Circular Valorization	Supporting Evidence
Biomass utilization	40–60% of shrimp biomass discarded	Up to 60–70% recoverable biomass	[7,11]
Waste management cost	50–150 EUR tonne ^{−1} disposal cost	Disposal costs partially offset by recovered products	[9]
Main recovered products	Limited (landfill, incineration, low-value uses)	Chitin, chitosan, astaxanthin, bioactive peptides	[12,14]
Market value	No economic return	Chitin: 10–20 EUR kg ^{−1} ; Astaxanthin: 2000–7000 EUR kg ^{−1}	[11–13]
Environmental impact	High BOD (>20,000 mg L ^{−1}); eutrophication and GHG emissions	Reduced waste generation and improved resource efficiency	[10]
Processing technology	Waste treatment	Enzymatic hydrolysis, membrane filtration, fermentation	[14]
Value chain model	Linear (production → disposal)	Circular (production → recovery → high-value products)	[10,12]

4. Regulatory and Scientific Assessment of Refined Shrimp Peptide Concentrate

4.1. Regulatory Framework

Although RSPC originates from foods (i.e., shrimp) that have been consumed by humans for centuries, its safety cannot be assumed *a priori* because of potential differences in composition and possible alterations induced by the industrial extraction and purification processes used to obtain it from shrimp waste materials, which may alter its safety profile. The overall procurement, processing and regulatory authorization pathway of Refined Shrimp Peptide Concentrate (RSPC) within the European Union is summarized in Figure 1.

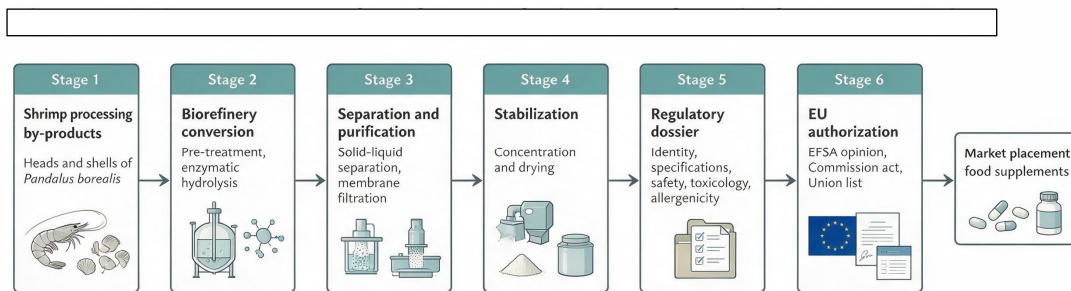


Figure 1. RSPC procurement and regulatory authorization pathway in the EU.

On the one hand, the impact of manufacturing process variables was appropriately assessed to support its safety as a novel food. The risk of contamination by proteases used during industrial processing has been assessed, and the filtration step was properly validated to exclude the presence of impurities in the final products. On the other hand, safety was assessed through an in-depth evaluation of the composition and the nutritional and toxicological characteristics of RSPC [15]. In particular, most of the available evidence was obtained from derivatives of *P. borealis* (northern shrimp), which is particularly abundant in the Atlantic Ocean. These consist mostly of short peptides: about 99.9% of all peptides in the final products are small peptides with a molecular weight lower than 2 kDa, which could be readily hydrolyzed to individual amino acids before systemic uptake. From a nutritional point of view, this peptide concentrate showed an amino acid profile similar to shrimp meat, suggesting that no differences in toxicity are expected compared with products already present in diets. This was further confirmed by acute toxicity and genotoxicity studies conducted by the sponsors: no adverse effects and/or chromosomal aberrations were observed in mouse models treated up to 2000 mg/kg [15,16]. Overall, the results supported the safety of the authorized maximum daily dose of 1200 mg. Indeed, this is the dose used in clinical studies to investigate whether RSPC may help maintain healthy blood pressure levels and support cardiovascular health. This interest is grounded in previous literature evidence on a specific ACE-inhibitory activity of the small peptides contained in shrimp, particularly when peptides with high concentrations of Gly and Pro were used [15,17]. The potential effects of RSPC on blood pressure were investigated in a total of 206 subjects with mild or moderate hypertension [15,18], evidencing a significant reduction in systolic blood pressure versus placebo over the 8-week intervention, without safety concerns. In this light, RSPC was authorized in 2017 in Canada and in 2018 in the EU as a novel food [19,20].

4.2. Scientific Evidence Supporting Safety

Regulation (EU) 2015/2283 defined an updated authorisation framework for novel foods before placing on the market, defined as foods without a significant history of consumption in the European Union before 15 May 1997 and falling under certain categories, including ingredients of animal origin obtained through post-1997 processes that significantly modify composition or structure. Within this framework, refined marine peptide concentrates produced from shrimp processing by-products, such as enzymatically hydrolysed *P. borealis* shells and heads, are defined as novel foods because the resulting peptide fractions differ substantially from conventionally consumed shrimp and lack a documented history of consumption in the EU.

Market access is contingent upon inclusion in the Union list of authorised novel foods, following a centralised procedure whereby food business operators submit a dossier to the European Commission and then to EFSA, which conducts a risk assessment [21]. The dossier must provide detailed information on raw material sourcing, manufacturing steps

(e.g., hydrolysis, purification and drying), product specifications (including peptide content and molecular weight distribution), stability, anticipated intake levels, and a comprehensive toxicological package, ideally complemented by human data. EFSA evaluates these data in line with the precautionary principle, with particular attention to potential allergenicity related to the crustacean origin, process-induced changes in composition, and the margin of safety at proposed use levels. A favourable opinion from EFSA allows the European Commission to adopt an implementing act adding the ingredient to the Union list, together with binding conditions for its use, such as authorised food categories (typically food supplements), maximum daily doses for specific population groups, and any mandatory labelling requirements, including allergen information. This structured approach not only ensures a high level of consumer health protection but also provides regulatory certainty for food operators seeking to position marine-derived peptide concentrates as high-value ingredients within a circular blue bioeconomy.

In the United States, marine peptide concentrates intended for use in dietary supplements are regulated under the Federal Food, Drug, and Cosmetic Act within the framework for dietary ingredients and new dietary ingredients (NDI) [22]. A shrimp-derived peptide concentrate is considered a dietary ingredient by virtue of its amino acid and peptide nature, but if it was not marketed in dietary supplements before 15 October 1994, it is generally classified as an NDI. In such cases, manufacturers or distributors are required to submit a pre-market NDI notification to the Food and Drug Administration at least 75 days before marketing the supplement [23]. The notification must demonstrate a “reasonable expectation of safety” under the proposed conditions of use and therefore includes data on ingredient identity, manufacturing process, specifications, anticipated intake, and toxicological evidence, which may encompass animal studies and, where available, human data. Unlike the EU novel food system, the NDI process does not culminate in a formal authorisation or admission in a technical list; instead, FDA receives the notification, can raise objections if appropriate, and retains enforcement powers if subsequent information indicates safety concerns [23]. As a result, marine-derived peptide concentrates obtained from shrimp by-products are evaluated case-by-case, with the regulatory focus placed on safety substantiation rather than on the novelty of the process or the circularity of the raw material. Overall, as showcased in Table 2, the EU and US systems illustrate two distinct but convergent pre-market paradigms for marine bioactive peptides: a highly codified authorisation with explicit conditions of use in the EU, and a notification-based, risk-oriented model in the US; both of these aspects must be addressed by developers who aim to valorise shrimp by-products by transforming them into marketable and scientifically validated functional ingredients.

Table 2. Key regulatory differences specific to marine peptides.

Aspect	EU—Novel Food (RSPC Example)	US—NDI (Shrimp Peptide Concentrate Example)
Legal Trigger	“Novel food” if no significant EU consumption pre-1997, or new process significantly alters composition/structure, including marine peptide concentrates from by-products.	“New dietary ingredient” if not marketed in supplements before 15 October 1994, regardless of traditional food use of the source species.
Procedure Type	Centralised authorisation: EFSA risk assessment, Commission implementing act, inclusion in Union list with binding conditions (dose, categories, labelling notes).	Pre-market notification: 75-day NDI notification to FDA, no formal authorisation act, no central positive list; FDA can object or take enforcement action.
Data Requirements	Full novel food dossier; detailed composition of peptide mixture (e.g., >99.9% peptides, size distribution), production from shrimp by-products, stability, toxicology, human trials, allergenicity.	Sufficient data to support a “reasonable expectation of safety”: identity, manufacture, specs, intake estimates, toxicology; level of detail negotiated case-by-case via NDI guidance.

Table 2. Cont.

Aspect	EU—Novel Food (RSPC Example)	US—NDI (Shrimp Peptide Concentrate Example)
Outcome for Shrimp Peptides	Explicit authorisation as a novel food ingredient in food supplements at up to 1200 mg/day for adults, with documented margin of exposure.	Acceptance (no objection) of an NDI notification allows marketing, but conditions (e.g., dose, target population) are not codified in a harmonised list.
Policy Context	Strongly linked to precautionary principle and to EU strategies on blue bioeconomy and circular use of marine by-products, valorising waste streams under strict pre-market control.	More risk-based and flexible; accommodates marine bioactives from by-products within the dietary supplement market, with FDA intervening mainly when safety concerns emerge.

4.3. Circular Bioeconomy and Value Chain Perspectives

The transition towards circular economy models in the seafood sector is increasingly recognized as a strategic priority to address resource inefficiencies, environmental pressures, and economic sustainability challenges. Within this framework, waste-to-value strategies aim to transform processing side streams into high-value products, thereby closing material loops and reducing dependency on primary resources. According to FAO, the sustainable management and valorization of aquatic bioresources are central to the concept of Blue Transformation, which promotes more efficient, inclusive, and resilient aquatic food systems [10].

In the seafood sector, circular economy approaches are particularly relevant due to the high proportion of by-products generated along the food value chain. It is estimated that up to 30–50% of total fish and seafood biomass is lost or discarded during processing, representing a significant inefficiency in resource use [8]. Waste-to-value strategies, including the recovery of bioactive compounds, proteins, and biopolymers, enable the reintegration of these materials into productive systems, supporting a transition from linear to circular production models.

From an environmental perspective, the adoption of circular approaches can substantially reduce the ecological footprint of seafood production. The valorization of by-products contributes to waste reduction and improves overall resource efficiency, limiting the need for primary raw materials and reducing pressures on marine ecosystems. According to the European Commission, circular economy strategies have the potential to reduce greenhouse gas emissions in the EU by up to 450 million tonnes of CO₂ equivalent by 2030, mainly through improved resource efficiency and waste valorization [24].

In the seafood sector, reducing waste streams is particularly relevant given the high biological value of discarded materials. FAO estimates that improving utilization of fisheries and aquaculture by-products could significantly enhance resource efficiency and contribute to global food security, reducing pressure on primary production systems [8]. In addition, circular bioeconomy strategies are associated with reductions in energy use and water consumption across processing stages, particularly when integrated biorefinery approaches are applied [10].

From an economic perspective, the transition towards circular models enables the creation of new value chains and the diversification of revenue streams.

The Organisation for Economic Co-operation and Development highlights that circular economy practices can generate substantial economic benefits by increasing resource productivity and reducing material costs, which in some industrial sectors can represent up to 40–60% of total production costs [25]. In seafood systems, this translates into the opportunity to convert low-value by-products into high-value compounds for food, feed, and nutraceutical applications. Evidence from OECD case studies illustrates how circular economy principles have already generated new value chains across different sectors and regions [25]. For example, organic waste streams are increasingly converted into

biogas and biofertilizers through anaerobic digestion, creating additional revenue while reducing landfill disposal. Construction and demolition waste is recovered as secondary raw materials for new buildings, lowering extraction costs and stimulating markets for recycled materials. In the agri-food sector, food residues are transformed into animal feed, compost, or bio-based chemicals, extending the value of biomass beyond primary food production. Similar circular approaches are now emerging in the seafood sector, where processing by-products such as fish frames, skins, viscera and crustacean shells are no longer regarded as waste but are increasingly recovered for the production of fishmeal, fish oil, collagen, gelatin, chitin, chitosan and marine bioactive compounds. As illustrated in Table 3, these examples demonstrate that circular business models create additional revenue streams, stimulate industrial innovation and strengthen regional competitiveness while simultaneously reducing environmental impacts and resource consumption [25].

Table 3. Illustrative examples of circular economy value chains across sectors, adapted from OECD (2020), with specific reference to seafood by-product valorization.

Sector	Circular Strategy	New Value Chain	Economic Benefit
Organic waste	Anaerobic digestion	Biogas and biofertilizers	Additional revenue and reduced disposal costs
Construction	Recycling of demolition waste	Secondary construction materials	Lower raw material costs
Agri-food	Valorization of food residues	Animal feed, compost, and bio-based chemicals	Diversified income streams
Seafood	Recovery of fish and shellfish by-products	Fishmeal, fish oil, collagen, gelatin, chitin, chitosan, and bioactive peptides	High-value marine bioproducts and reduced waste

To place the RSPC case study within its broader economic context, the following macroeconomic indicators describe the development of the European circular bioeconomy. These indicators provide contextual information and should not be interpreted as direct measures of the economic performance of RSPC or shrimp peptide production. The bioeconomy sector already represents a significant economic component in Europe. According to the European Commission, the EU bioeconomy employs over 17 million people (around 8% of total EU employment) and generated an estimated turnover of up to €2.7 trillion in 2023, highlighting its strategic role in supporting sustainable growth and circular innovation [26]. Although these figures refer to the overall European bioeconomy rather than to marine peptide ingredients specifically, they illustrate the economic framework within which innovative marine-derived products such as RSPC may contribute to future value creation. Within this context, marine bioresources and seafood side streams are increasingly recognized as strategic assets for the development of high-value bio-based industries.

From a social perspective, circular and blue economy strategies contribute to job creation and regional development, particularly in coastal and rural areas. The expansion of activities such as biomass recovery, processing, and biorefinery operations supports the creation of “green jobs” and enhances local economic resilience. According to the International Labour Organization, the transition to a greener economy could generate up to 24 million new jobs globally by 2030, particularly in sectors related to sustainable resource management, circular production systems, and bio-based industries. Although the specific employment contribution of shrimp peptide valorization cannot currently be quantified, technologies such as RSPC production represent one example of the innovative bio-based activities expected to support this broader transition towards sustainable seafood systems [27].

Overall, the integration of circular and blue economy principles in seafood systems enables a systemic transition from waste management to resource valorization, delivering combined environmental, economic, and social benefits. This approach strengthens the sustainability and competitiveness of marine-based industries while contributing to broader policy objectives related to climate change mitigation, resource efficiency, and inclusive growth.

5. Challenges and Future Perspectives

5.1. Current Challenges

Despite the promising potential of marine-derived novel foods such as refined shrimp peptide concentrate (RSPC), several challenges remain influencing their large-scale adoption and integration into sustainable food systems.

One of the primary concerns relates to allergenicity and consumer safety. As RSPC is derived from crustaceans, it falls within one of the major allergen groups identified under European food law, requiring strict risk assessment and clear labeling requirements. In fact, EFSA emphasizes that allergenicity assessment remains a critical component in the authorization of novel foods, particularly when processing technologies may alter protein structures and potentially affect allergenic potential [28]. Ensuring consumer safety therefore requires not only robust toxicological and clinical evidence but also continuous post-market monitoring.

In addition to safety aspects, industrial scalability and cost-efficiency represent key challenges for the commercialization of marine bioactive compounds. While laboratory-scale processes such as enzymatic hydrolysis and membrane filtration have demonstrated high efficiency, their upscaling to industrial levels often involves significant capital investment and operational costs. According to FAO, the adoption of innovative processing technologies in fisheries and aquaculture sectors is frequently constrained by economic barriers, particularly for small and medium-sized enterprises [10]. Achieving cost-competitive production therefore requires process optimization, economies of scale, and allocation of funds to help in the transition and integration within existing seafood processing infrastructures.

Consumer acceptance is another critical factor influencing the market success of marine-derived novel foods. Despite increasing interest in sustainable and functional foods, products derived from by-products or “waste” streams may face perception barriers related to food safety, quality, and cultural acceptance. The European Commission has highlighted that consumer trust and transparency are key drivers for the adoption of novel foods, particularly in the context of sustainability-oriented innovations [24]. Effective communication strategies, including clear labeling, health claims supported by scientific evidence, and education on circular economy benefits, are therefore essential to enhance consumer acceptance.

From a policy perspective, the integration of novel food innovation into circular and blue economy strategies requires coordinated regulatory and economic frameworks. While Regulation (EU) 2015/2283 provides a robust safety-based authorization system, further alignment with circular economy and bioeconomy policies is needed to fully support the valorization of marine by-products. The Organisation for Economic Co-operation and Development emphasizes that policy coherence across innovation, environmental, and economic domains is essential to enable the development of sustainable blue bioeconomy sectors [29].

Looking ahead, future developments should focus on enhancing the sustainability and economic viability of marine-derived novel foods through integrated approaches combining technological innovation, regulatory support, and market development. In particular, the implementation of techno-economic assessments and life cycle analysis

will be crucial to quantify the environmental and economic performance of valorization pathways. At the same time, fostering collaboration between research institutions, industry stakeholders, and policymakers will be essential to scale up innovative solutions and ensure their successful integration into resilient and circular food systems.

Overall, addressing these challenges will be fundamental to unlocking the full potential of marine bioresources within the blue economy, enabling the transition towards more sustainable, resource-efficient, and economically viable food production models.

5.2. Current Limitations and Future Research

This review has some limitations that should be considered when interpreting its findings. First, it was designed as a narrative review supported by a regulatory case study, rather than as a systematic review or meta-analysis, and therefore the literature was selected based on its relevance to the objectives of the study rather than through a formal quality assessment. Second, the discussion is primarily centred on the EFSA Scientific Opinion on Refined Shrimp Peptide Concentrate (RSPC), which was used as a representative case study to explore the interaction between novel food regulation, marine by-product valorization, and sustainable seafood systems. Consequently, the findings should be interpreted with caution when extrapolating the conclusions to other marine-derived novel foods. Finally, although macroeconomic indicators from international organizations were included to provide the broader policy and economic context of circular bioeconomy strategies, no product-specific techno-economic analysis, life cycle assessment (LCA), or quantitative value chain modelling was performed. Future research should integrate these approaches to quantify the environmental, economic, and commercial performance of RSPC and to support the industrial scale-up of marine-derived functional ingredients.

6. Conclusions

Refined Shrimp Peptide Concentrate (RSPC) represents one of the first examples of a marine-derived functional ingredient whose commercialization has been supported by a comprehensive EFSA safety assessment under Regulation (EU) 2015/2283. By examining this regulatory case study, the present review highlights how scientific evidence, food safety evaluation and seafood by-product valorization converge in the development of innovative marine-derived novel foods.

The analysis also shows that the regulatory assessment extends beyond toxicological evaluation, encompassing manufacturing processes, compositional characteristics, nutritional quality, allergenicity and proposed conditions of use. Consequently, the EFSA opinion provides a valuable framework for understanding the scientific requirements that future marine-derived novel foods are expected to satisfy before market authorization. At the same time, the review identifies important knowledge gaps that remain insufficiently addressed. Although the valorization of shrimp processing by-products is widely recognized as a promising strategy within sustainable seafood systems, quantitative evidence on industrial scalability, techno-economic feasibility, life cycle performance and long-term market competitiveness is still limited. Integrating these dimensions with regulatory assessment will be essential for translating scientific innovation into commercially viable products.

Overall, the RSPC case demonstrates that regulatory approval can play a pivotal role in supporting the transition from low-value seafood processing residues to high-value functional ingredients. Future research should combine regulatory science with environmental and economic assessment to provide a more comprehensive understanding of the contribution of marine-derived novel foods to sustainable seafood production and circular bioeconomy objectives.

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