Review Article

CHITOSAN APPLICATION IN AQUATIC FEED AND ITS IMPACT ON FISH AND SHRIMP PRODUCTIVITY

ABSTRACT

The culture of crustaceans, such as shrimp and crabs, in Indonesia has resulted in a significant increase in waste production, particularly in the form of shells and heads. This waste contains valuable components like chitin, chitosan, and carotenoids, which can be extracted and utilized in aquaculture activities. Chitosan, derived from chitin, is a functional polysaccharide with various biological activities, including antimicrobial, anti-inflammatory, and immune-stimulating effects. It also acts as a growth promoter in shrimp and improves the performance of farmed fish. Additionally, the inclusion of chitin and chitosan in fish feed formulations enhances digestibility, growth, and nutrient absorption. This paper provides a comprehensive review of the potential, nutritional value, and benefits of processed crustacean waste products, focusing on chitosan, and their impact on the productivity of fish in aquaculture.

Keywords: aquaculture, crustacean waste, chitosan, fish feed, performance, shrimp

1. INTRODUCTION

The cultivation of crustaceans, including shrimp and crabs, has witnessed significant growth in Indonesia. However, this growth has led to an increase in waste generated from the crustacean industry, primarily in the form of shells, heads, and shells. Shrimp and crabs have shells that comprise a substantial proportion (50-60%) of their total weight, containing valuable components such as chitin (20-30% content). In the case of shrimp, the shell waste and shrimp heads from the annual export of 91,176 tonnes amount to approximately 36,470 tons, while crab processing yields a waste volume roughly half that of shrimp. Failure to utilize this waste not only contributes to environmental pollution but also poses challenges to maintaining environmental sanitation due to the decomposition-associated unpleasant odor.

Shrimp and crab waste possess considerable potential as sources of chitin, chitosan, and carotenoids, all of which can be utilized in aquaculture activities. Chitin can be extracted from shrimp and crab shells through demineralization and deproteination processes. Subsequently, chitin can be further processed into chitosan through a deacetylation process. Furthermore, the shells of shrimp, which contain carotenoids, particularly astaxanthin, can be processed to obtain carotenoid-rich compounds using non-polar solvents, edible oils, or enzymatic methods employing protease enzymes like trypsin. Consequently, the waste-derived products obtained from these processes can be effectively utilized as additives in fish feed. This paper aims to comprehensively review the potential, nutritional value, and benefits of processed crustacean waste products, with a particular focus on chitosan, and their impact on the performance of farmed fish.

2. CHITOSAN: STRUCTURE, SOURCES, AND NUTRITIONAL CONTENT

Chitosan, a result of deacetylation of chitin, is a long-chain polymer of glucosamine (2-amino-2-deoxy-glucose) [1] (Figure 1). While insoluble in organic solvents like dimethyl sulfoxide and at pH 6.5, chitosan readily dissolves in organic acid solutions, with acetic acid being an effective solvent [2].

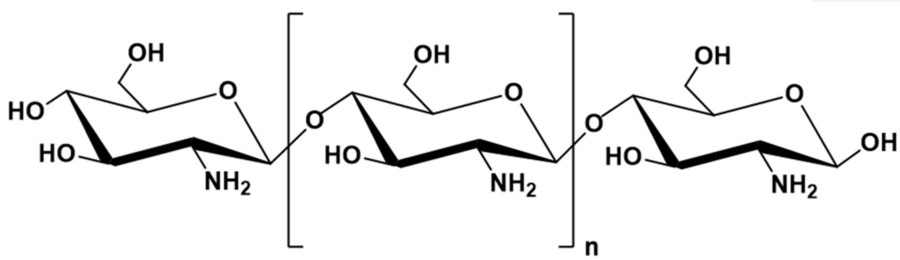

Fig. 1. Chitosan chemical structure
Source: [3]

Chitosan, a polyglucosamine, exhibits solubility in various acids such as acetic, lactic, and organic acids (adipic, malic), as well as mineral acids like HCl and HNO_3, at a concentration of 1%. However, it has limited solubility in phosphoric acid and is insoluble in sulfuric acid. With its amine group as a functional group, chitosan displays a high degree of chemical reactivity [4]. [5] noted that chitosan carries a positive charge in solution due to the presence of amine groups, distinguishing it from other polysaccharides that are typically negatively charged or neutral. The quality of chitosan varies according to its intended use, with higher purity required for pharmaceutical applications compared to wastewater treatment processes [6].

Chitosan can be obtained from various crustaceans, such as shrimp, crabs, and crayfish, in the form of shells, heads, and exoskeletons. Additionally, chitin, the precursor of chitosan, is found in diverse sources. It is widely distributed in nature and serves as a major component of exoskeletons in marine invertebrates. Chitin is also present in the structural composition of insects, arthropods, and molluscs. Figure 2 illustrates the primary sources of chitin production and extraction. From a nutritional standpoint, chitosan exhibits favorable nutritional value (Table 1), making it a viable ingredient in fish feed formulations.

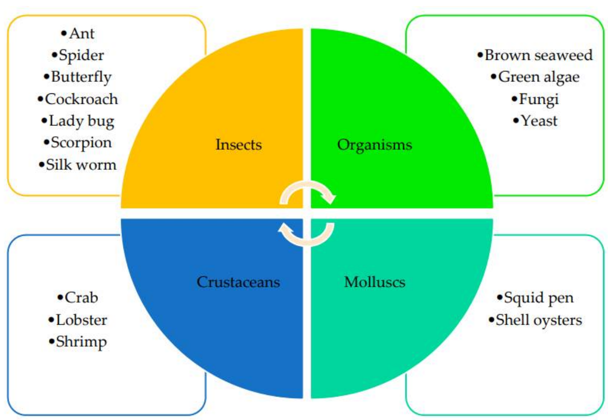

Fig. 2. Sources of chitin production

Table 1. Characteristics of shrimp shell chitosan

Specification	% dry basis		
	Analysis Results	**ESFA 2010**	**GRAS 2012**
Color	Brownish white	-	White to off white powder
Odor	Odorless	-	Neutral
Flake	Form	-	18-120 mesh
Moisture content (%)	12.29	≤ 10	≥ 10
Ash content (%)	0.99	≤ 3	≥ 0.5
Fat content (%)	3.13	≤ 1	-
Total nitrogen (%)	2.20	≤ 6	0.02g/100g
Carbohydrates (%)	81.39*	-	-
Viscosity (cPs)	1713.04	-	25-5000
Degree of deacetylation	98.65	≥ 90	75-95

Description: *) by difference

3. ROLE OF CHITOSAN IN FISH AND SHRIMP FEED

Chitin and chitosan, carbohydrate polymers found in crustacean waste, offer diverse applications, including their use as additives in fish and shrimp feeds. Additionally, crustacean waste contains valuable carotenoids, which can be extracted from chitosan and utilized as additives in aquaculture and ornamental fish feeds, enhancing color intensity.

In aquaculture, chitosan plays a crucial role in improving the performance of farmed fish. As a functional polysaccharide, chitosan exhibits various biological activities, such as haemostatic properties [7], anti-inflammatory effects [8], antitumor potential [9],[10], antimicrobial activity [11], hypoglycemic and hypocholesterolemic effects [12],[13], as well as immune-stimulating properties [14],[15]. Chitosan, containing glucosamine derived from chitin, can serve as a growth promoter in shrimp, primarily by accelerating carbohydrate metabolism [16],[17],[18],[19]

Moreover, [18] reported that the inclusion of chitin at levels of 1% to 4% in shrimp feed enhances digestibility and growth. This finding suggests that shrimp have an improved ability to absorb and utilize glucose from the feed source. Similarly, it is anticipated that glucosamine from chitin sources can stimulate the growth of other aquatic organisms. In addition, chitosan supplementation in feed demonstrates immune-stimulating effects, enhances nutrient digestion and absorption, and increases protein content in Indian major carp (*Labeo rohita*), consequently improving growth performance [20].

Furthermore, [21] found that chitosan protects α-fold acid antioxidant compounds from damage caused by heat, light, and acidic conditions. Chitosan has emerged as a promising growth promoter in animal feeds. [22] further revealed that the addition of chitosan to milkfish feed mitigates the odor of mud attributed to geosmin, as chitosan binds with the geosmin compound and facilitates its excretion through feces, thereby reducing the characteristic odor.

4. FISH AND SHRIMP PERFORMANCE BASED ON CHITOSAN FEED

Numerous research studies have investigated the effects of chitosan-based feed on the productivity of fish and shrimp in the aquaculture industry. Table 2 provides a concise overview of the key findings from these studies, highlighting the outcomes of employing chitosan in feed formulations.

Table 2. Several research related to chitosan-based feed

Treatment	Result	References
Use of chitosan in milkfish	In this study, the optimal results were achieved when incorporating 10 ppm of chitosan into the feed formulation, which effectively reduced the mud odor in milkfish. The feeding duration of 4 days was found to be the most effective in reducing the mud smell. Proximate analysis revealed that the fat and carbohydrate contents decreased in milkfish treated with the best formulation (10 ppm chitosan for 4 days) compared to the control. Conversely, there was an increase in ash content and protein percentage in the treated group compared to the control	[23]
The use of chitosan for carp growth	Supplementing fish feed with 8.0% chitin has shown a positive impact on growth response and feed utilization in carp. The inclusion of chitin at this concentration resulted in improved growth performance and enhanced feed utilization efficiency	[24]
Use of chitosan for tilapia growth	The optimal treatment for chitosan supplementation in tilapia was found to be at a dose of 100 ppt. This treatment resulted in a feed conversion ratio (FCR) of 3.48 ± 2.25, average growth rate (SGR) of 0.85 ± 0.84, average protein gain (APG) of 28.70 ± 16.54. Statistical analysis (ANOVA) indicated that all chitosan treatments did not have a significant effect (P>0.05) on the number of erythrocytes and leukocytes in tilapia	[25]
Use of chitosan for shrimp growth	The addition of chitosan to the feed during a 30-day rearing period exhibited a significant effect on the specific growth rate (SGR) and protein retention in vannamei shrimp. The highest SGR was observed with the addition of 4% chitosan, which was not significantly different from the inclusion of 3% chitosan. Similarly, increased protein retention was achieved by incorporating 4% chitosan, without significant difference from the addition of 3% chitosan	[26]

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5. CONCLUSION

The utilization of crustacean waste, particularly shells and heads, presents an opportunity to harness valuable components such as chitin, chitosan, and carotenoids for the enhancement of aquaculture activities. Chitosan, derived from chitin, has shown significant potential as a functional polysaccharide with various biological activities and as a growth promoter in shrimp. Its inclusion in fish feed formulations improves digestibility, growth, and nutrient absorption. By effectively utilizing these waste-derived products as additives in fish feed, the aquaculture industry can benefit from enhanced productivity and sustainability.

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Further research and development in this area are warranted to optimize the utilization of crustacean waste and maximize its potential in aquaculture practices.

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