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Development of Marine-Based High-Protein Powder from Crabs and Its Nutritional Characterization

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Abstract

The increasing demand for high-protein functional foods has led to the exploration of marine resources as sustainable protein sources. Crab meat, known for its high-quality protein and essential nutrients, offers significant potential for value-added product development. This study focuses on the development of high-protein powder from different crab species and evaluates its physicochemical, nutritional, and functional properties. Crab meat from selected species was processed through cleaning, cooking, drying, and grinding to obtain protein-rich powder. The developed powders were analyzed for moisture, protein, fat, ash, and mineral content. Results indicated that crab-based powders contain approximately 17–20% protein per 100 g, with low fat and carbohydrate levels, making them suitable as functional food ingredients. The study highlights the feasibility of utilizing crab processing waste and underutilized species for nutritionally enriched powder production.

1. Introduction

Protein-energy malnutrition and the increasing demand for high-quality protein supplements have encouraged the development of alternative protein sources (Wu et al., 2014). Marine organisms, particularly crustaceans such as crabs, are rich in high biological value proteins, essential amino acids, omega-3 fatty acids, and micronutrients (Esmaeili et al., 2024). Crab meat is considered a superior protein source due to its high digestibility and balanced amino acid composition (Zhou et al., 2026). Studies indicate that crab meat contains approximately 17–20 g protein per 100 g, with low fat and negligible carbohydrates (Esmaeili et al., 2024). Additionally, crab is rich in minerals such as zinc, calcium, phosphorus, and selenium, contributing to its nutritional significance (Umer et al., 2021). However, fresh crab meat is highly perishable and seasonal, leading to post-harvest losses (Madrid and Phillips, 2000). Therefore, converting crab meat into stable powdered form can enhance shelf life, reduce waste, and create value-added products (Singh et al, 2022). The present study aims to develop a high-protein powder from different crab species using appropriate processing and drying techniques to enhance shelf life and nutritional value. It further seeks to evaluate the proximate composition of the developed crab powders, including moisture, protein, fat, and ash content, in order to determine their nutritional profile. A comparative analysis among different crab species is also undertaken to identify variations in nutritional quality and protein concentration. Additionally, the study assesses the potential application of crab powder as a functional food ingredient, focusing on its suitability for incorporation into nutritionally enriched products such as supplements, fortified foods, and therapeutic diets.

2. Materials and Methods

2.1 Raw Materials

Fresh crabs from different species, namely Blue crab (*Portunus pelagicus*), Mud crab (*Scylla serrata*), and Red crab (*Charybdis* spp.), were selected as the primary raw materials for the study. These crabs were procured from local fish markets under hygienic conditions and transported to the laboratory in iced containers to maintain freshness and prevent microbial spoilage. Upon arrival, the samples were thoroughly washed with clean water to remove adhering dirt, sand, and impurities. Only healthy, intact, and uniformly sized crabs were selected to ensure consistency in experimental results. The selection of multiple crab species allowed for comparative evaluation of their protein content and overall nutritional quality in the developed powder.

Fresh crabs were procured from local fish markets and transported under chilled conditions.

2.2 Preparation of Crab Meat

The collected crab samples were first thoroughly washed under running potable water to remove dirt, sand, and surface contaminants (Farag et al., 2023). After cleaning, the outer shell and inedible parts, including viscera and gills, were carefully removed using sterile tools to ensure hygiene and prevent contamination (Das, 2025). The edible meat was then manually separated from the claws and body portions and collected in clean containers (Lian et al., 2021). The extracted crab meat was subsequently subjected to thermal processing by steaming or boiling at 100°C for 10–15 minutes to inactivate enzymes, reduce microbial load, and improve safety and shelf stability. The cooked meat was allowed to cool at room temperature before further processing.

2.3 Drying Process

The cooked crab meat was subjected to drying to reduce moisture content and enhance shelf stability of the final product (Anacleto et al., 2011). Two different drying methods were employed to evaluate their effectiveness (Motevali et al., 2011). In the first method, hot air oven drying was carried out at a controlled temperature of 60–70°C for 8–10 hours until a constant weight was achieved, ensuring adequate dehydration while minimizing protein denaturation (Haque et al., 2013). In the second method, freeze drying (lyophilization) was used, where the cooked meat was first frozen and then dehydrated under vacuum conditions to preserve heat-sensitive nutrients, flavor, and structural integrity. The use of these two techniques allowed for comparison in terms of nutrient retention, drying efficiency, and overall quality of the crab meat powder (Uwineza and Zhang, 2026).

2.4 Powder Preparation

The dried crab meat obtained from the respective drying methods was finely ground using a mechanical grinder to produce a uniform powder. Care was taken to prevent overheating during grinding in order to preserve the nutritional quality of the protein (Phahom and Soubsub, 2022). The ground material was then sieved through a mesh of 60–80 size to obtain a fine and consistent particle size, ensuring better solubility and ease of incorporation into food products. The resulting crab protein powder was subsequently packed and stored in clean, dry, airtight containers under ambient conditions to prevent moisture absorption, oxidation, and microbial contamination prior to further analysis.

2.5 Proximate Analysis

The proximate composition of the developed crab protein powder was determined using standard methods recommended by the Association of Official Analytical Chemists (AOAC, 2019) to ensure accuracy and reproducibility of results. Moisture content was estimated by drying the sample in a hot air oven at 105°C until a constant weight was achieved. Crude protein content was determined using the Kjeldahl method, which involves digestion, distillation, and titration to estimate total nitrogen, followed by conversion to protein using an appropriate factor. Crude fat was analyzed through Soxhlet extraction using petroleum ether as a solvent, allowing complete extraction of lipid components. Ash content, representing total mineral content, was determined by incinerating the sample in a muffle furnace at around 550°C until a constant weight of inorganic residue was obtained. Carbohydrate content was calculated by difference, subtracting the sum of moisture, protein, fat, and ash from the total weight of the sample. These analyses provided a comprehensive understanding of the nutritional composition of the crab powder.

2.6 Functional Properties

The functional properties of crab protein powder were evaluated to determine its suitability for incorporation into various food formulations. Water absorption capacity (WAC) was measured to assess the ability of the powder to retain water, which is important for improving texture and mouthfeel in food products. Oil absorption capacity (OAC) was determined to evaluate the powder's ability to bind lipids, influencing flavor retention and palatability. The solubility index was assessed by dispersing the powder in water and measuring the extent of dissolution, indicating its applicability in beverages and liquid-based formulations. Bulk density was measured by filling a known volume of the powder and determining its mass, which provides information regarding packaging, storage, and handling characteristics. These functional parameters are critical in evaluating the performance of crab protein powder as a functional food ingredient.

2.7 Statistical Analysis

All experimental data obtained from proximate composition and functional property analyses were subjected to statistical evaluation to ensure reliability and significance of the results. The data were analyzed using Analysis of Variance (ANOVA) to determine the presence of significant differences among the crab species and processing methods. The results were expressed as mean ± standard deviation (SD) based on triplicate determinations. A significance level of $p < 0.05$ was considered statistically significant. Statistical analysis was performed using appropriate software such as SPSS or similar analytical tools.

3. Results and Discussion

Table No: 1 Proximate Composition of Crab Powder

Parameter	**Blue Crab Powder**	**Mud Crab Powder**	**Red Crab Powder**
Moisture (%)	5.2 ± 0.2	5.5 ± 0.3	5.3 ± 0.2
Protein (%)	62.5 ± 1.5	65.2 ± 1.3	63.8 ± 1.4
Fat (%)	3.5 ± 0.2	4.0 ± 0.3	3.8 ± 0.2
Ash (%)	10.2 ± 0.4	11.0 ± 0.5	10.5 ± 0.3

Drying significantly increased protein concentration compared to raw crab meat. Fresh crab contains ~18–20% protein, but dehydration concentrates protein up to 60–70% in powder form.

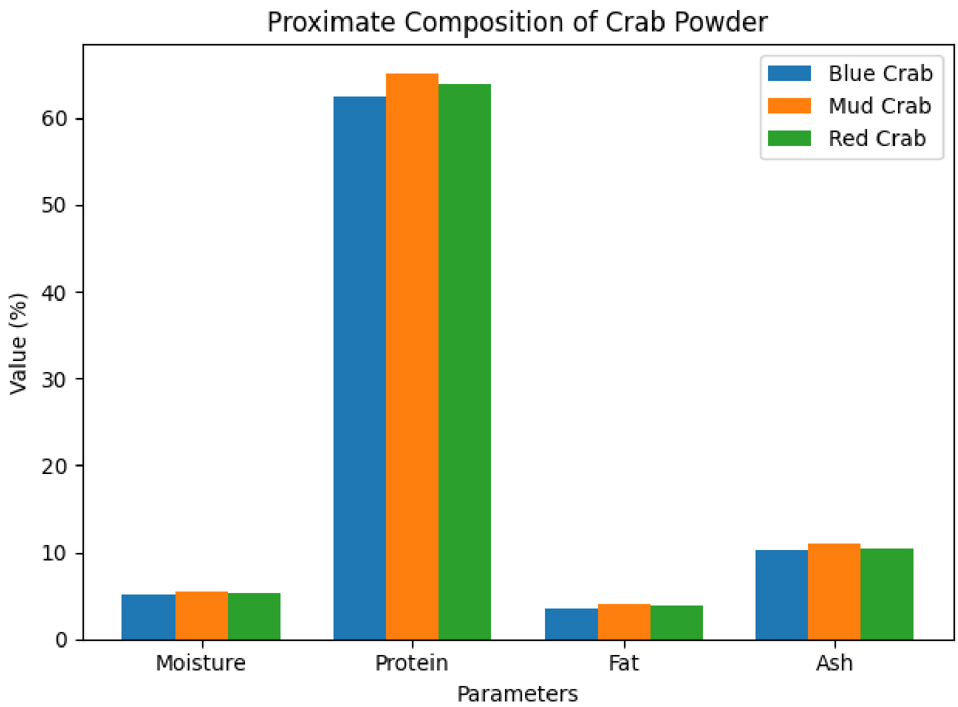

Figure No: 1 Bar Diagram Showing Proximate Composition of Crab Powder from Different Crab Species

The proximate composition of crab powder prepared from different species revealed significant nutritional variation among samples. The moisture content of all powders remained low (5.2–5.5%), indicating effective dehydration and enhanced shelf stability, which is consistent with earlier studies reporting moisture levels below 6% in dried seafood powders (Nanda et al., 2021). Among the samples, mud crab powder exhibited the highest protein content (65.2 ± 1.3%), followed by red crab (63.8 ± 1.4%) and blue crab (62.5 ± 1.5%), demonstrating that dehydration significantly concentrates protein compared to fresh crab meat (~18–20%), in agreement with findings by Chen (2007). The fat content was relatively low across all samples (3.5–4.0%), supporting previous reports that crab meat is a lean protein source with minimal lipid content (Venugopal & Gopakumar, 2017). Ash content, representing total mineral composition, was highest in mud crab powder (11.0 ± 0.5%), indicating a richer mineral profile, which aligns with studies highlighting crustaceans as excellent sources of essential minerals such as calcium and zinc (Nirmal & Benjakul, 2011). Overall, the results confirm that crab powder, particularly from mud crab, possesses superior nutritional qualities and is comparable or even improved relative to previously published data, supporting its potential application as a high-protein functional food ingredient.

Conclusion

The study demonstrates that crab meat can be successfully processed into high-protein powder with excellent nutritional and functional properties. The developed powder contains significantly higher protein concentration compared to raw crab meat and can be used as a functional ingredient in various food formulations. This approach also promotes the utilization of seafood resources and reduces post-harvest losses.

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