EVALUATION OF THE NUTRITIONAL POTENTIAL OF SHRIMP SHELL WASTE AS A SOURCE OF DIETARY FIBER

Ludmilla Silva Sampaio Santos[a,b], Ronnie Emanuel Pereira Pinto[a,b], Paulo Sérgio Sobral Júnior[a,b], Gabriela Pereira Barros[a,b], Joyce Mikellyne Penha[a,b], Adriana de Jesus Santos[a,b], Ranyere Lucena de Souza[a,b]

[a] *Tiradentes University, Aracaju – SE, Brazil*
[b] *Institute of Technology and Research, Aracaju – SE, Brazil*

Abstract: This study explores the potential of shrimp shells, rich in chitin, antioxidants, and fiber, as a source of matrix for various industrial sectors. Physical-chemical analyses of shrimp shell flour showed a moisture content of 7.53%, 15.31% ash, 5.37% lipids, 6.76% fiber, and a high protein content of 41.23%. Through spectroscopy, functional groups were identified in the structure of the shells, with a peak absorption at 3420 cm-1. In addition, the research aims to determine the feasibility of incorporating shrimp shells into industry sectors in order to maximize the value of the waste, revealing new possibilities for the use of aquaculture by-products and contributing to a more sustainable approach.

Keywords: *Extraction, shrimp shells, dietary fiber, nutrition*.

1. INTRODUCTION

According to data from the Ministry of Agriculture, Livestock and Supply of Brazil (MAPA) for 2024, the Brazilian crustacean production industry is in a growth phase. In Brazil, shrimp farming production reached the mark of 7.86 million tons, showing an annual growth of 7.52% [1]. The main producing region is the Northeast due to its characteristics, such as high temperatures and short periods of rain, with the states of Rio Grande do Norte and Ceará being the largest national producers [2], with an estimated value of 2.30 billion reais [3].

Shrimp farming in Brazil is notable and stands out for the dominance of technology in production and high acceptance in the consumer market, favoring its commercialization. According to the Brazilian Association of Shrimp Farmers (ABCC), in terms of shrimp farming practice areas, the most cultivated shrimp in Brazil is the Pacific white shrimp, scientifically known as Litopenaeus vannamei, originated in the Pacific Ocean. It is noteworthy that this species is generally cultivated in saltwater ponds, located mainly in Rio Grande do Norte, Ceará, Pernambuco, Paraíba, and Bahia [2].

Shrimp shells, widely discarded by the seafood processing industry, have notable, yet unexplored potentials, however, as the crustacean processing industry grows, the amount of waste produced, such as shells, carapaces, viscera, and water used for washing and disposal, expands. This waste is discarded into the environment, resulting in problems for both the ecosystem and public health [4].

As highlighted by Rios et al., (2020), shrimp-related waste contains high concentrations of organic matter, lipids, proteins, minerals, among other compounds [5]. Therefore, it is necessary to develop technologies capable of ensuring the preservation of these compounds, transforming these by-products for reinsertion into the market or industry [6], reducing harm to biodiversity and increasing the quality of

life of communities residing near the areas where this waste is discarded.

Albuquerque et al., (2023), highlights the importance of this waste, which is rich in chitin and chitosan, with a focus on the food sector for the production of films and coatings with antimicrobial and antioxidant properties, in the microencapsulation of compounds, in addition to being used as agents for removing heavy metals [7]. Furthermore, Guedes et al., (2025), highlights the use of chitosan in the development of polymeric films for the incorporation of active pharmaceutical ingredients due to their characteristics such as permeability, solubility, mechanical resistance, and biocompatibility, which are essential properties for the protection of sensitive drugs [8].

Thus, this study aims to evaluate the potential of shrimp shell waste and its compounds through chemical and physicochemical characterization techniques as an alternative for possible industrial applications.

2. METHODOLOGY

2.1 Material

The shrimp shells used in this study were obtained in March 2023 from Império dos Mariscos, located at the Augusto Franco Market, in a single batch. Initially, the shells were carefully washed to eliminate shrimp meat residues, lipids, and other materials. Subsequently, they were boiled and rinsed with distilled water. To remove residual moisture, the shells were dried in an oven at 50 °C for 24 hours. After drying, the shells were ground in a knife mill and sieved using a mesh with a 16 to 100 mesh opening. The resulting material was then stored in glass containers for later use.

2.2. Physicochemical evaluation of shrimp shell waste

The following analyses were performed in triplicate at the Food Research Laboratory (LPA) located at the Institute of Technology and Research (ITP) of Tiradentes University.

2.2.1 Moisture determination

The fresh mass loss of a 2 g sample of the shrimp shell waste was determined in an oven at 105 °C until constant weight.

2.2.2 Lipid determination

The adopted methodology extracted lipids hot in a Soxhlet extractor, from a 6 g aliquot of the shrimp shell waste sample. The method is based on the solubility of lipids with nonpolar solvents in reflux equipment, with the solvent used being PA petroleum ether.

2.2.3 Fiber determination

The defatted sample was subjected to an acid digestion with a 1.25% sulfuric acid solution, then it was subjected to an alkaline digestion with a 1.25% sodium hydroxide solution. The sample was vacuum filtered and all the remaining residue was washed with distilled water and incinerated in a muffle furnace at 550 °C until ash was formed.

2.2.4 Protein determination

The Kjeldahl method was chosen for the quantification of nitrogen in a sample. This method comprises three steps: sample digestion, distillation, and titration. In digestion, 0.2 g of the shrimp shell waste sample was weighed to be digested with concentrated sulfuric acid in the presence of 1.5 g of catalyst (96% K_2SO_4 + 4% $CuSO_4 5H_2O$). Next, the formed ammonium bisulfate reacted with sodium hydroxide to release ammonia, in the form

of ammonium borate. The ammonia was released, within the known volume of boric acid. The formed ammonium borate was titrated with a standardized hydrochloric acid solution to obtain the nitrogen content.

2.3 Fourier Transform Infrared Spectroscopy (FTIR)

The shrimp shell samples were analyzed by FTIR, using a BOMEM MB-100 spectrophotometer. The analyses were conducted at 25 °C on an Agilent Cary 630 FTIR model spectrometer, using the transmission method in the wavenumber range between 4000 and 500 cm-1, with 32 scans and a resolution of 4 cm-1, performed at the Food Research Laboratory (LPA) located at the Institute of Technology and Research (ITP) of Tiradentes University.

2.4 Scanning Electron Microscopy (SEM)

The characterization of the microstructure of the in-natura and defatted shrimp shell was performed by the electron microscopy technique. The images of the sample surfaces were generated with magnifications of 9,000 to 15,000 times and with energy of 5 and 15 kV, the samples were deposited on a metallic substrate adhered to a carbon tape and covered with a layer of gold. The SEM tests were performed on a Jeol brand Scanning Electron Microscope, model JSM – 7500F belonging to the Laboratories of the Multiuser Center for Nanotechnology (CMNano) of UFS.

3. RESULTS AND DISCUSSION

The chemical composition of shrimp shell was evaluated according to standard AOAC (2020) procedures and highlighted in table 1. The moisture content of the residue was determined to be 7.53% (w/w). Seabra et al., 2014, and Vieira et al., (2011), found moisture contents close to this work, with 5.12% and 8.90% respectively [9-10]. The higher moisture content found in this research indicates that the shorter drying time may have influenced this parameter. The presented ash content, 15.31%, is in a higher range than that reported by Brasileiro et al., (2012), 6.59% and Fernandes et al. (2013), 4.35% [11-6]. These differences may have arisen due to variations in the types of residues, since the mentioned authors used shrimp cephalothorax, while, in this study, the use of the exoskeleton was opted for, a part rich in minerals and chitin.

According to the results obtained (Table 1), the shrimp shell flour presented 5.37% lipids, a value higher than those found by Brasileiro et al., (2012) and Fernandes (2009), who obtained 3.16% and 1.10%, respectively [11-12]. This difference may be related to the exclusive use of shells in this study, while the others used the complete residue (cephalothorax and exoskeleton). The fiber content was 6.76%, lower than the 8.92% reported by Rosenfeld et al., (1997) for the seven-bearded shrimp (Xiphopenaeus kroyeri), possibly due to the difference between the species [13]. As for the protein content, the analyzed flour presented 41.23%, this value is below the values obtained by Lima et al., (2007) and Fernandes (2009), with 66.01% and 50.01%, respectively, when using other residual parts of the shrimp [14-12]. These data suggest that the cephalothorax may represent a higher alternative source of protein compared to other anatomical parts.

3.1. Fourier Transform Infrared Spectroscopy (FTIR)

From the spectroscopy performed on the in-natura and defatted shrimp shell samples, it was possible to determine the presence of functional groups present in their structure, as shown in Figure 1. It was observed that, for both in-natura (A) and defatted (B) samples, the FTIR analysis found the same functional groups, with the absorption peak observed at 3420 cm-1 referring to the hydroxyl group (OH), indicating the presence of amine (Nordin et al., 2025) [15]. At 1660 cm-1 there are C=O bonds, frequently found in biological substances, at 1560 cm-1 the amide II group and at 1100 cm-1 the carbonyl group (C-O), with the presence of C-O bonds (Mamad et al., 2025) [16]. From the result obtained, it is noted that the defatting treatment of the sample is an indifferent factor in the determination of functional groups, as the same groups were obtained for the treated and untreated sample. With this, the removal of lipids present in the sample does not alter its chemical composition and structure, and the in-natura form can be used without pre-treatment for potential industrial applications.

3.2. Scanning Electron Microscopy (SEM)

Figure 2 (a, b) shows the micrograph obtained for the in-natura shrimp shell and for the defatted sample. The result obtained shows agglomerates and particles with magnitudes of 300x for both samples. It is noted that, from the microscopic evaluation, it is possible to observe particles with regular geometric conformation and with a large distribution of pores.

Also observed is the morphology of the shrimp shell, highlighting that in both samples the particles showed homogeneity and compaction, such as the presence of aggregates with the formation of orifices due to diffusion between the particles. In both samples, the presence of calcium carbonate was detected, represented by the whitish coloration in the particles [17]. This result demonstrates that the pre-treatment is effective, showing a structure similar to the in-natura residue, thus being able to be applied in several industrial sectors due to its high distribution of pores that can be filled with molecules of interest.

4. CONCLUSION

The study proposes a sustainable approach, aligned with the current needs of the food industry, highlighting the importance of using this waste in a responsible manner, which can bring benefits to human health, reduce resource waste and contribute to food security and environmental preservation. From the physicochemical analyses, it was possible to verify that the shrimp shell flour reached a moisture content of 7.53%, 15.31% ash, 5.37% lipids, 6.76% fiber and 41.23% protein. With spectroscopy, functional groups were identified in the shell structure, reaching an absorption peak at 3420 cm –1.

Acknowledgments

This study was financed in part by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior [CAPES]—Finance Code 001; Conselho Nacional de Desenvolvimento Científco e Tecnológico [CNPq].

Tables, figures and graphics

Tabela 1. Nutritional characterization of shrimp shell flour in comparison with other studies.

Protein (%)	Lipid (%)	Fibers (%)	Moisture (%)	Ref.

41,23	5,37	6,76	7,53	Original work
66,01	ND	ND	ND	Lima *et al.*, (2007)
50,01	1,10	ND	ND	Fernandes (2009)
ND	3,16	ND	ND	Brasileiro *et al.* (2012)
ND	ND	8,92	ND	Rosenfeld *et al.*, (1997)

Figure 1. Fourier Transform Infrared Spectroscopy (FTIR) for fresh (A) and defatted (B) shrimp shells.

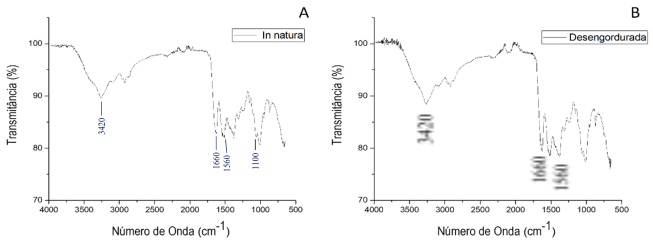
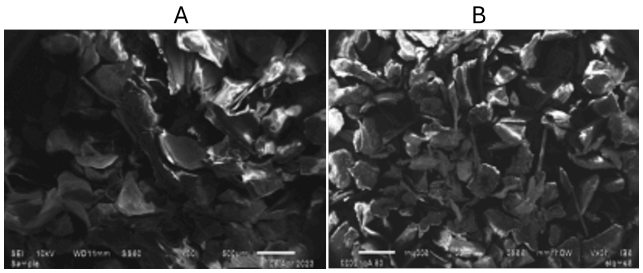


Figure 2. Morphology of shrimp shells (a) in natura and (b) defatted



REFERENCES

[1] Ministério da Agricultura, Pecuária e Abastecimento (MAPA). Boletim da Pesca e Aquicultura, 2020. Disponível em: http://www.agricultura.gov.br/assuntos/aquicultura-e-pesca/boletins-da-pesca-e-aquicultura. Acesso em: 16 mar. 2023.

[2] INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Pesquisa da Pecuária Municipal. Censo agropecuário, 2019.

[3] XIMENES, L.; VIDAL, M. Carcinicultura. Caderno Setorial ETENE, v. 8, n. 274, 2023.

[4] DE OLIVEIRA ORNELA, P. H., GUIMARÃES, L. H. S. Utilização de resíduos da indústria pesqueira do camarão na produção de quitinases pelo fungo Aspergillus niveus em fermentação em substrato sólido Utilization of shrimp fishing industry waste in the production of chitinases by the fungus Aspergillus niveus in solid-state fermentation. *Brazilian Journal of Development*, *8*(5), 33846-33862, 2022.

[5] Rios, F. S., de Souza, G. B., Silva, F. O., Machado, F. R., de Oliveira, C. M., & da Silva,R. C. Crustacean waste generation and disposal: Environmental and public health impacts. Journal of Environmental Management, 267, 110563. 2020.

[6] FERNANDES, T. M. *et al.* Flour production from shrimp by-products and sensory evaluation of flour-based products. Pesquisa Agropecuária Brasileira, v. 48, n. 8, p. 962-967. 2013.

[7] ALBUQUERQUE, K. G. S., COSTA, M. R., SANTOS, J. K. D. L., MARINHO, J. P. A., Lira, D. K. F. D., ALMEIDA, G. E. C. D., ARAÚJO, F. G. D. Produção de quitosana a partir de resíduos de crustáceos e aplicação na indústria de alimentos: uma revisão de literatura. OPEN SCIENCE RESEARCH XI, 11, 1314-1331, 2023.

[8] GUEDES, G. G., DE SOUSA SILVA, A. B. A., DE MACEDO, A. C., DA SILVA NASCIMENTO, K. V., DO NASCIMENTO, J. L., DE ARAÚJO MEDEIROS, K., DE LIMA DAMASCENO, B. P. G. Obtenção de filmes poliméricos: propriedades físico-químicas e aplicações na indústria farmacêutica. Novas tecnologias aplicadas à Engenharia Biomédica: Progresso e perspectivas na Engenharia de tecidos Volume 2, 9, 2025.

[9] SEABRA, Larissa Mont'Alverne Jucá; DAMASCENO, Karla Suzanne Florentino da Silva Chaves; SILVA, Camila Ricioli; GOMES, Camila de Carvalho; PEDROSA, Lucia Fátima Campos. Total carotenoids in white shrimp (*Litopenaeus vannamei*) waste. Revista Ceres, v. 61, n. 1, p. 130-133, 2014.

[10] VIEIRA, Sidely Gil Alves; FOGAÇA, Fabíola Helena dos Santos; FERREIRA, Irani Alves; RODRIGUES, Anastácia Amália Damasceno; GOMES, Thiago Nobre. Técnicas para elaboração da farinha de cabeça de camarão marinho (Litopenaeus vannamei). Teresina: Embrapa Meio-Norte, 4 p. 2011

[11] BRASILEIRO, O. L. et al. Determination of the chemical composition and functional properties of shrimp waste protein concentrate and lyophilized flour. Ciência e Agrotecnologia, v. 36, n. 2, p. 189–194, 2012.

[12] FERNANDES, Thiago Mendes. Aproveitamento dos subprodutos da indústria de beneficiamento do camarão na produção de farinha. 2009. 84 f. Dissertação (Mestrado em Ciência e Tecnologia de Alimentos) – Universidade Federal da Paraíba, João Pessoa, 2009.

[13] ROSENFELD, D. J. et al. The effect of using different levels of shrimp meal in broiler diets. Poultry Science, v. 76, n. 4, p. 581-587, 1997.

[14] LIMA, Stélio Bezerra Pinheiro de; RABELLO, Carlos Bôa-Viagem; DUTRA JUNIOR, Wilson Moreira; LUDKE, Maria do Carmo Mohaupt Marques; COSTA, Fernando Guilherme Perazzo. Avaliação nutricional da farinha da cabeça do camarão marinho (Litopenaeus vannamei) para frangos de corte. Revista Caatinga, v. 20, n. 3, p. 38-41, 2007.

[15] Nordin, N., Ambia, N. F. A. Z., Majid, S. R., & Bakar, N. A. Efficient encapsulation of a model drug in chitosan cathodic electrodeposition: Preliminary analysis using FTIR, UV–vis, and NMR spectroscopy. Carbohydrate Polymers, 348, 122830. 2025.

[16] Mamad, D. M., Muhammad, D. S., Aziz, S. B., Muheddin, D. Q., Ahmed, B. Y.,

Abdalkarim, K. A., ... & Abdullah, O. G. Improvement the optoelectronic properties of chitosan biopolymer using natural dye of black olive as a novel approach: FTIR, XRD and UV–vis spectroscopic studies. Optical Materials, 164, 117057. 2025.

[17] Gbenebor, O., Adeosun, S., Lawal, G., Jun, S., & Olaleye, S. Acetylation, crystalline and morphological properties of structural polysaccharide from shrimp exoskeleton. Engineering Science and Technology, an International Journal, 20, pp. 1155-1165. 2017.