Shrimp Waste Utilization; Industrial and Food Applications

Ashmitha J Mishma[1] and R. Emilin Renitta[2]

[1]Research Scholar, Division of Food Processing Technology, Karunya Institute of Technology and Sciences, Coimbatore, 641114.

[2]Associate Professor, Division of Food Processing Technology, Karunya Institute of Technology and Sciences, Coimbatore, 641114,

Corresponding Author: emilinrenitta@karunya.edu

Introduction

Seafood is an extremely perishable product with a high nutritional value. India is the 3rd largest fish producing country in the world, contributing about 8% of global fish production and ranked 2nd in aquaculture production (PIB report, 2023). It is also among the top five seafood exporting countries in the world, of which the major product is frozen shrimp (Indian Trade Portal report, 2023). According to the MPEDA export performance (2023-24) report, India exported 17, 81602 MT of seafood, which contributed 40.19% of shrimp by quantity and 62.12% by total export value. Globally, 5.6 million tons of shrimp were produced by 2023, which is projected to increase to 7.28 million tons by 2025 (Jory, 2023). Commercially important shrimp species include *Penaeus vannamei* and *Penaeus monodon* (Kumar et al. 2022). As shrimp production has increased, the shrimp-processing industry has undergone a dramatic increase in recent years. During processing, approximately 50-60% of the waste is generated as by products, such as exoskeleton, head, pleopod, pereopod, and uropod (tail). This waste has a significant negative impact on the environment, such as environmental pollution, or produces unpleasant odour if not properly disposed. Shrimp waste and shrimp by-products are rich in both micronutrients and bioactive compounds, which are necessary for the human body and create many new opportunities for the food and nutraceutical sectors (Abuzar et al., 2023). Shrimp processing includes three categories for export purposes (Anh et al., 2011): i) whole shrimp, ii) de-headed shrimp, and iii) peeled shrimp. For processing purposes, shrimp were collected either from the catch or hatcheries. As soon as these shrimps reach the processing units, they can be processed on the same day or stored in the freezer and used later. Initially, they are washed in normal water to remove impurities followed by sorting according to the requirement and the removal of damaged and decomposed material as waste or low-grade products. For hygiene purposes, these sorted products are again washed in iced chlorinated water and separated into different categories according to export requirements (Nirmal et al., 2020). The frozen products are stored at -22^{0}C, and sodium metabisulfite is used as an additive in processing plants (Nirmal & Benjakul, 2011).

Valuable parts of Shrimp Waste

Shrimp waste is rich in potentially important compounds such as carotenoids, chitin, protein, protein hydrolysate, chitosan, and minerals. According to Su et al. (2023) shrimp head contain 14 different types of endogenous proteases. In addition, shrimp head is a good option for consumption, as its sodium potassium ratio is less than 1.5 (Abuzar et al., 2023). Additionally, they are rich sources of PUFA, essential amino acids, crude protein, and micro-and macronutrients. Among shrimp wastes, the highest concentrations of EPA and DHA were found in shrimp shells and exhibit antioxidative properties. The cephalothorax and head contain pigmented oils that are rich in beneficial nutrients such as omega 3 fatty acids, unsaturated fatty acids, mono-and diesters of free fatty acids, astaxanthin, palmic acids, and oleic acids. These parts are of high importance and can be further used for the development of diverse value-added products in various industries, such as food, feed, and non-food applications, such as nutraceuticals (Abuzar et al., 2023).

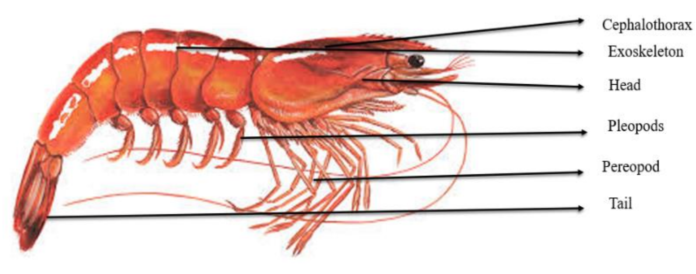

Fig. 1. Valuable parts of shrimp waste.
Image Source - Image: https://www.seafoodwatch.org

Applications

Shrimp waste is used to produce bio-based commodities that are extremely valuable source of biomolecules with commercial significance such as chitosan, protein, astaxanthin rich oil, and chitin. They have various application in food (fig.2a) and feed industries, non-food applications (fig.2b) such as nutraceuticals, and in environmental and biotechnical applications.

Food Applications

Astaxanthin, and chitosan are the most important by products obtained from shell waste. In order to improve the nutritional content of food products, incorporation of astaxanthin and chitosan is a popular technique (Abuzar et al., 2023). Astaxanthin has a wide range of uses, including as a colouring agent and vitamin supplement in fortified foods - that are enhanced with nutrients like vitamins, minerals, fibre, and protein (Dave et al., 2020a). Protein hydrolysate extracted from shrimp shell debris has been used in the food industry to maximise the nutritional value of food items by supplementing protein content and enhancing anti-oxidant qualities. Chitosan is added in the food products to enhance the quality of food (Abuzar et al., 2023) and also be used as food emulsion stabilizer (Yang et al., 2023). In bakeries, utilization of microencapsulated shrimp oil helped to increase the volume of bread loaf and provides the desired red and yellow hues to the bread crumbs and crust after fortification (Takeungwongtrakul et al., 2015). Table 1 shows the products and its practical applications.

Table 1. Practical food application of shrimp waste by products

Products	Practical Applications	References
Seafood broth, soup, flavour seasoning	Used in seafood-based products and also improve shelf life.	Bassig et al., 2022
Astaxanthin based products	Used for the production of value-added products such as oil, astaxanthin powder, natural colouring agent and in medicines.	Wang et al., 2021, Dave et al., 2020b
Fortified peach drinks	For the production of cholesterol free drink.	Raju et al., 2022 & Gulzar & Benjakul, 2020
Oils, carotenoids, Lipids	Nitrogen flushing during ultrasonication helps to increase the oxidative property of lipids.	Gulzar & Benjakul, 2020
Shrimp protein and concentrate	Potential ingredient in the food and feed formulation, and protein enriched products.	Gulzar & Benjakul, 2020
Spiced flour and flavoured biscuits	Enrichment of protein in food applications	Gonçalves & dos Santos Junior, 2019
Yogurt fortified with Astaxanthin	For the development of fortified products.	Taksima et al., 2015

Feed applications: Shrimp processing waste contains nutritive and bioactive ingredients, including protein, carotene, chitin, and lipids, and is utilized in the manufacture of animal feed (Pattanaik et al., 2020) and improves digestibility in juveniles (Lu & Ku, 2013). Additionally, the growth performance and immunity of farmed fish may be enhanced by waste processing (Gisbert et al., 2018). Astaxanthin extracts exhibit strong antibacterial and antioxidant activities (Weeratunge and Perera, 2016). Gisbert et al., (2018) in his study evaluated the protein extracted from cephalothorax of *L.vannamei* as a feed supplement enhance the fish immune response without negatively impacting the growth performance.

Non-Food Applications

Shrimp products are used in non-food and industrial applications because they can be used to produce a wide range of environmentally beneficial and reasonably priced goods depending on the accessibility and affordability of each product. Astaxanthin possesses diverse antioxidant properties, making it suitable for industrial applications. The use of astaxanthin to make composite films plays an important role in the food packaging industry and is widely used as a protective, antibacterial, antioxidant, and preservation film. Chitosan gelatine films and chitin composites have also been used in the food packaging industry (Xu et al., 2020). Edible bioplastics are also made from chitosan, which is safe for packing and consumption because of its favourable mineral content and lack of heavy metals (Dasumiati et al., 2019).

Nutraceuticals

The global demand for food production enhanced by nutraceuticals has increased significantly in the modern period. Prawn waste has several functional properties that can help with a variety of illness, and it is becoming more viable supply to address the demand. Nutraceuticals have expressed strong interest in lipid extraction from shrimp, as they contain high amounts of astaxanthin, DHA, and EPA. These lipids help reduce cholesterol and are high in polyunsaturated fatty acid (PUFA) content (Raju & Benjakul, 2020). It has been discovered that the utilization of peptides from shrimp waste in functional foods contain advantageous compounds for the treatment of hypertension. Shrimp shells are used as scavenging agents against antioxidant activity and as natural preservatives (Sayari et al., 2018; Raju & Benjakul, 2020). During Polycystic Ovarian Syndromes (PCOS), ovarian tissue suffers from significant oxidative stress damage, in addition to the development of insulin resistance. It was observed that Metformin corrected insulin resistance improved PCOS. During this period, Astaxanthin (ASX) combined with metformin prevented oxidative stress damage to the ovary (Toktay et al., 2023).

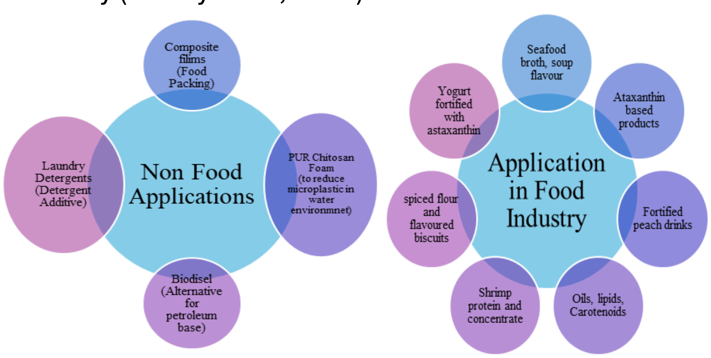

Fig 2a Fig 2b

Fig 2 (a). Application of shrimp waste in food industry. (b) Potential use of shrimp waste in non-food industry

Environmental and biotechnological application

a) Waste water remediation

Shell powder has been studied as a potential biopolymer for the removal of Fe, Al, Mn, Co, and Ni from polluted waters (Núñez-Gómez et al., 2017). Because of the high chitin and calcium carbonate contents in the shell powder, they effectively remove heavy metals from polluted water (Núñez-Gómez et al., 2019).

b) Energy Conservation

Shrimp debris rich in chitin, when added to heteroatoms (such as S and P), may enhance the capacity for adsorption, catalytic efficiency, and electrochemical activity (Mondal et al., 2017). Therefore, shrimp shell-based N, P-doped catalysts could be efficient in air-cathode microbial fuel cells for energy generation (Zheng et al., 2020).

Potential benefits of Shrimp waste utilization

Protein hydrolysates from shrimps are regarded as valuable sources of protein because of their beneficial antioxidant characteristics (Pereira et al., 2022). The hydrolysed enzyme obtained from the byproducts of *Pandalus borealis* is used to reduce hypertension and control oxidative stress because of its high molecular weight (Kim et al., 2016). The antimicrobial characteristics of chito-oligomers are used to fight pathogenic microorganisms in the foregut as they enhance gut health; these oligomers are also added to the diet (Varun et al., 2017). Carotenoids have various applications in various fields, such as cosmetics and food colorants (Nguyen et al., 2021).

a) Antioxidant Activity
   i. Helps in the protection and safety of skin.
   ii. Prevents the damage of hepatic induced with activities of enzymes.
   iii. Tyrosinase inbition is used in funtional foods.
b) Anticancer Activity
   i. Bioactive compounds extracted can be used for the treatment of breast cancer, colon cancer, gastric cancer, tongue cancer.
c) Immune boosting
   i. Helps in the prevention of immunopathology
   ii. Helps in reducing antioxidative stress (Xie et al., 2020).
   iii. Improved growth of fish (Subramanian et al., 2020).
d) Fertility Enhancement
   i. Increased sperm production
   ii. Decrease the idiopathic infertility
   iii. Treats PCOS (Jabarpour et al., 2023)

Conclusion: Shrimps are one of the most important seafood commodities across the world. As the demand have been increasing, the processing companies have also increased leading to the increased production of wastage. This generated waste contains huge number of bioactive compounds and nutrients which exhibit various bioactivities such as anti-oxidant, anti-hypertension, anti-inflammation, etc. Some of these bioactive compounds can be served as functional foods and in feed industries to improve the quality and functional properties of foods. The future trends for shrimp processing includes the complete utilization of shrimp debris without creating additional waste. More recently, shrimp waste has been used for some biotechnological and environmental application such as remedies for waste water treatment, oil spills and energy conservation. Hence, recycling of the shrimp waste is important, which will reduce the organic load on environment instead of dumping.

References

Abuzar, Sharif, H. R., Sharif, M. K., Arshad, R., Rehman, A., Ashraf, W., Karim, A., Awan, K. A., Raza, H., Khalid, W., Asar, T. O., & Al-Sameen, M. A. (2023). Potential industrial and nutritional applications of shrimp by-products: a review. International Journal of Food Properties, 26(2), 3407–3432.

Bassig, R., Obinque, A., Nebres, V., Santos, V., Peralta, D., & Madrid, A. (2022). Utilization of Shrimp Head Wastes into Powder Form as Raw Material for Value-Added Products. The Philippine Journal of Fisheries, 191–200.

Comhaire, F. H., Garem, Y. El, Mahmoud, A., Eertmans, F., & Schoonjans, F. (2005). Combined conventional/antioxidant "Astaxanthin" treatment for male infertility: a double blind, randomized trial. Asian Journal of Andrology, 7(3), 257–262.

Darwesh, O. M., Sultan, Y. Y., Seif, M. M., & Marrez, D. A. (2018). Bio-evaluation of crustacean and fungal nano-chitosan for applying as food ingredient. Toxicology Reports, 5, 348–356.

Dave, D., Liu, Y., Pohling, J., Trenholm, S., & Murphy, W. (2020a). Astaxanthin recovery from Atlantic shrimp (Pandalus borealis) processing materials. Bioresource Technology Reports, 11, 100535.

Dave, D., Liu, Y., Pohling, J., Trenholm, S., & Murphy, W. (2020b). Astaxanthin recovery from Atlantic shrimp (Pandalus borealis) processing materials. Bioresource Technology Reports, 11, 100535.

Dhinaut, J., Balourdet, A., Teixeira, M., Chogne, M., & Moret, Y. (2017). A dietary carotenoid reduces immunopathology and enhances longevity through an immune depressive effect in an insect model. Scientific Reports, 7(1), 12429.

Gonçalves, A. A., & dos Santos Junior, J. (2019). Shrimp processing residue as an alternative ingredient for new product development. International Journal of Food Science & Technology, 54(9), 2736–2744.

Gulzar, S., & Benjakul, S. (2020). Impact of pretreatment and atmosphere on quality of lipids extracted from cephalothorax of Pacific white shrimp by ultrasonic assisted process. Food Chemistry, 309, 125732.

Jabarpour, M., Aleyasin, A., Nashtaei, M. S., Lotfi, S., & Amidi, F. (2023). Astaxanthin treatment ameliorates ER stress in polycystic ovary syndrome patients: a randomized clinical trial. Scientific Reports, 13(1), 3376.

Jory, D. (2023). Annual farmed shrimp production survey: A slight decrease in production reduction in 2023 with hopes for renewed growth in 2024. *Global Seafood Alliance: Portsmouth, NH, USA*.

Raju, N., Gulzar, S., & Benjakul, S. (2022). Cholesterol-lowered shrimp lipid-loaded liposome stabilised by pectin/glycerol and its fortification in peach tea drink. International Journal of Food Science & Technology, 57(3), 1563–1572.

Santos, S. D., Cahú, T. B., Firmino, G. O., de Castro, C. C. M. M. B., Carvalho Jr., L. B., Bezerra, R. S., & Filho, J. L. L. (2012). Shrimp Waste Extract and Astaxanthin: Rat Alveolar Macrophage, Oxidative Stress and Inflammation. Journal of Food Science, 77(7).

Srinivasan, H., Kanayairam, V., & Ravichandran, R. (2018). Chitin and chitosan preparation from shrimp shells Penaeus monodon and its human ovarian cancer cell line, PA-1. International Journal of Biological Macromolecules, 107, 662–667.

Subramanian, K., Sadaiappan, B., Aruni, W., Kumarappan, A., Thirunavukarasu, R., Srinivasan, G. P., Bharathi, S., Nainangu, P., Renuga, P. S., Elamaran, A., Balaraman, D., & Subramanian, M. (2020). Bioconversion of chitin and concomitant production of chitinase and N-acetylglucosamine by novel Achromobacter xylosoxidans isolated from shrimp waste disposal area. Scientific Reports, 10(1), 11898.

Takeungwongtrakul, S., Benjakul, S., & H-Kittikun, A. (n.d.). Characteristics and Oxidative Stability of Bread Fortified with Encapsulated Shrimp Oil. In Ital. J. Food Sci.

Taksima, T., Limpawattana, M., & Klaypradit, W. (2015). Astaxanthin encapsulated in beads using ultrasonic atomizer and application in yogurt as evaluated by consumer sensory profile. LWT - Food Science and Technology, 62(1, Part 2), 431–437.

Wang, L., Hu, J., Lv, W., Lu, W., Pei, D., Lv, Y., Wang, W., Zhang, M., Ding, R., & Lv, M. (2021). Optimized extraction of astaxanthin from shrimp shells treated by biological enzyme and its separation and purification using macroporous resin. Food Chemistry, 363, 130369.

Xie, S., Yin, P., Tian, L., Yu, Y., Liu, Y., & Niu, J. (2020). Dietary Supplementation of Astaxanthin Improved the Growth Performance, Antioxidant Ability and Immune Response of Juvenile Largemouth Bass (Micropterus salmoides) Fed High-Fat Diet. Marine Drugs, 18(12), 642.

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://pib.gov.in/PressReleaseIframePage.aspx?PRID=1910415#:~:text=India%20is%20the%20third%20largest,12.12%20Million%20Tonnes%20from%20Aquaculture.

https://www.indiantradeportal.in/vs.jsp?lang=0&id=0,31,24100,29402#:~:text=India%20is%20among%20the%20top,year%20was%20US%24%207.76%20billion.

https://mpeda.gov.in/wp-content/uploads/2024/06/Export-performance_2023-24-approved_V5.pdf

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