Fish Protein-Based Edible Films/Coatings from Seafood Processing Waste: A Smart Packaging Material for Fish and Fishery Products

Sathish Kumar K, Jeyakumari A., Elavarasan K and Bindu J
ICAR-Central Institute of Fisheries Technology, Cochin- 682 029
Corresponding Author: jeya131@gmail.com

The fisheries and aquaculture sectors have been recognized for their important contribution to global food security and nutrition in the 21st century. Due to this, the demand for fish and fishery products is ever-increasing, and they are traded worldwide in different processed forms. During processing, industries generate nearly 63 mmt of processing waste every year globally (Bhaskar et al., 2010). These wastes generated through the processing of fish, crab, and shrimp accounts 30-60%, 75-85% and 40-80% respectively (Rajeswari et al., 2018), in terms of fish head, viscera, tail, skin, bones, blood, liver, gonads and guts etc. To date, fishery wastes are partly destined for fishmeal, fertilizers, and fish oil production with less profit, and the remaining are thrown away into the environment, leading to pollution issues. This discarded waste has great nutritional value in terms of protein, lipids, minerals, and enzymes that have the potential for use in food, pharmaceutical, agricultural, and industrial applications.

Shelf-life extension of fish and fish products is another challenge for seafood industries since it is a highly perishable commodity. Generally, fresh fish are stored in ice or under refrigerated/chilled conditions during marketing. In these situations, shelf life is very limited due to lipid oxidation and microbial spoilage. This leads to huge economic losses to fish traders, retailers, and processors. Although synthetic preservatives are very efficient in maintaining the quality, the major concerns are their potential toxicity and carcinogenicity, which cause harmful effects to humans. Hence, fish processing industries and traders are actively searching for new, innovative, natural technologies to sustain the quality and safety of fish and fishery products during storage or marketing. Recently, active packaging systems have emerged to improve the shelf life and safety of food products. Among that, bioactive edible coating/films gained much attention due to their advantages, such as edibility, bioactivities, barrier to moisture, gas, and microorganisms (Rennie and sunjka, 2018). Furthermore, it enhances the nutritional value, sensory quality of products and could be an alternative for chemical preservatives.

Edible films/coatings are thin, continuous layers of edible materials, which can be applied on or between food components (Falguera et al., 2011). It provides barrier properties against moisture, oil, gases, improves mechanical properties, retains volatile compounds, and preserves the colour and texture of products (Flores et al., 2007). It is an ideal technique to mobilize the active antioxidant and antibacterial agents on the food surface and release them during the entire storage period, like a time-release function (Mingkang et al., 2011). Polysaccharides, proteins, and lipids are commonly used materials for edible films/coatings development. Among them, protein-based films/coatings have a greater attention due to their adherence to the hydrophobic food surface and minimize the oxygen and CO_2 transmission while arresting the drip loss (Sánchez-Ortega et al., 2014). Protein materials such as keratin and egg albumin, whey protein, soy protein, fish protein, gelatin, and collagen can be used for edible coating/film development. Generally, the seafood processing wastes consist of head, skin, viscera, and bone, which have high amounts of protein, fat, and minerals, etc. Extraction of protein from this waste could address the waste disposal and environmental pollution problems faced by the industries. It also increases the profit by converting waste into valuable fishery products. Furthermore, protein-based edible coatings/films can enhance the nutritional content and sensory quality of food products to attract consumers.

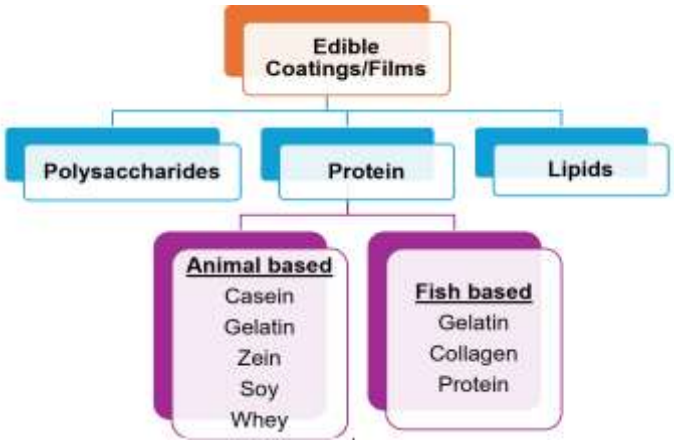

Fig.1. Schematic diagram of protein-based edible films/coatings from different sources

Fish Protein hydrolysate-based packaging films/coatings

Fish protein hydrolysate (FPH) is one of the most emerging high-value fishery products, due to its various applications in food, cosmetics, pharmaceutical, nutraceutical, and functional food industries, etc. Edible portion or processing discards from fish can be utilized for FPH production. Protein hydrolysate is the breakdown product obtained by enzymatic hydrolysis of protein from the muscle portion into smaller peptides, containing 2–20 amino acids. There are many research studies on the characterization of the functional and bioactive properties (Henriques et al., 2021; Undiganalu et al., 2022) of FPH. So, FPH can be used as a primary packing material to enrich the nutritional value of food products with improved functional properties (Najafian and Babji, 2012). The addition of bioactive compounds such as antioxidants and antimicrobials, essential oils, and extracts into these edible coatings/films is an effective and innovative method to enhance their antimicrobial properties, which will increase the shelf life of fish and fishery products.

Fish protein isolates-based packaging films/coatings

In the seafood industry, the isoelectric solubilization/precipitation method is used to recover protein from processing discards. In this method, proteins from the processing discards are solubilized in an acidic or alkaline medium and then centrifuged for precipitation. Then, the lipid layer on top and insoluble impurities such as bones and skin at the bottom are removed. The solubilized protein in the middle layer will be collected and precipitated at the isoelectric point of the fish protein. This precipitate is called fish protein isolate, which consists of sarcoplasmic and myofibrillar proteins. It has been reported that it can form a continuous matrix and synthesize edible packaging materials. The properties of the film depend on the protein concentration, temperature, and the type of plasticizer used (Rocha et al., 2013). Research has been carried out to develop biodegradable films using myofibrillar protein by adding polyphenols (Du et al., 2021), chitosan (Batista et al., 2019), oregano essential oil (Romani et al., 2017), and gelatin (Athanasopoulou et al., 2023) for better functional and mechanical properties.

Fish gelatin-based packaging films

Gelatin is another fish protein obtained by the hydrolysis of fibrous insoluble collagen from skin and scales, which are generated as waste during fish processing. It is one of the most used proteins for packaging film or coating preparation due to its better film-forming and barrier properties against light and oxygen (Etxabide et al., 2017). Generally, gelatin is extracted from diverse animal sources such as bovine, porcine, and fish to develop edible packaging films or coatings (Suderman et al., 2018). However, it exhibits poor water vapor barrier properties due to its hydrophilic nature. Further, some communities are not accepting the mammalian gelatin due to their socio-cultural-religious or health-related concerns (Lin et al, 2017). Therefore, gelatin from aquatic sources is a major focus for the seafood industry as a possible alternative to mammalian gelatin. In recent years, gelatin-based films have been used as carriers of natural bioactive compounds (antioxidants and antimicrobials, plant extracts, essential oils) to achieve active packaging functions (Adilah et al., 2018; Shahbazi, 2017). The interactions between bioactive compounds and gelatin matrix can provide controlled release of active ingredients over the storage period, with improved mechanical properties (Jridi et al., 2019).

Fish collagen-based packaging films

Collagen, a fibrous protein with typical triple helical structures, extracted from fish skin, bone, fin, and scales, which has good film-forming properties and biodegradability, makes it a suitable active food packaging material (Qiang et al., 2019). Due to the tight triple helical structure, collagen films display high tensile strength (Sionkowska et al., 2020). Generally, mechanical strength is crucial for any packaging material to maintain the integrity of food products. Up to now, collagen has been widely used to manufacture edible casings instead of plastic and natural casings owing to its good characteristics (Suurs & Barbut, 2020). Therefore, studies on collagen-based active packaging films/coatings have not been often reported.

Conclusion

Demands for environmentally friendly packaging materials have led the packaging industry to develop packaging materials obtained from natural and renewable resources, such as natural proteins from the seafood industry waste. However, protein films should be elastic, strong, and have barrier properties for their application in food packaging systems. Studies are aimed at improving the properties of protein-based films through plasticization, cross-linking techniques, and the preparation of composite films by blending with

other natural polymers such as polysaccharides and lipids. Overall, fish protein can meet the requirements of food packaging materials through various modifications. Additionally, the nutritional and sensory quality improvement makes the protein-based films/coatings one of the best choices of edible packaging materials, which leads to the commercialization of novel protein-based packaging.

References

Adilah, A. N., Jamilah, B., Noranizan, M. A., & Hanani, Z. N. (2018). Utilization of mango peel extracts on the biodegradable films for active packaging. Food Packaging and Shelf Life, 16,1–7.

Batista, J.T.S., Araújo, C.S., Peixoto Joele, M.R.S., Silva, J.O.C., Lourenço, L.F.H. (2019). Study of the effect of the chitosan use on the properties of biodegradable films of myofibrillar proteins of fish residues using response surface methodology. Food Packag. Shelf, 20 :100306

Bhaskar, N., Sachindra, N. M., Suresh, P. V. and Mahendrakar, N. S., 2010. Microbial reclamation of fish industry by-products. In: Montet, D. and Ray R. C. (Eds.). Aqua. Microbiol. Sci., 7: 248-75.

Du H., Liu C, Unsalan O., Altunayar-Unsalan C., Xiong S., Manyande A, Chen H. 2021.Development and characterization of fish myofibrillar protein/chitosan/ rosemary extract composite edible films and the improvement of lipid oxidation stability during the grass carp fillets storage. International Journal of Biological Macromolecules 184: 463–475

Etxabide, A., Uranga, J., Guerrero, P., & de la Caba, K. (2017). Development of active gelatin films by means of valorisation of food processing waste: A review. Food Hydrocolloids, 68, 192–198.

Falguera, V., Quintero, J. P., Jiménez, A., Muñoz, J. A. and Ibarz, A., 2011. Edible films and coatings: Structures, active functions and trends in their use. Tre. Food Sci. Technol., 22(6): 292-303.

Flores, S. L., Fama, A. M., Rojas, S., Goyanes. and Gerschenson, L., 2007. Physical properties of tapiocastarch edible films: influence of film making and potassium sorbate. Food Res. Int., 40: 257-265.

Getu, A., Misganaw, K. and Bazezew, M., 2015. Post-harvesting and major related problems of fish production. Fisheries and Aqua. J., 6: 4.

Henriques, A., Vázquez, J. A., Valcarcel, J., Mendes, R., Bandarra, N. M. and Pires, C., 2021. Characterization of Protein Hydrolysates from Fish Discards and By-Products from the North-West Spain Fishing Fleet as Potential Sources of Bioactive Peptides. Mar. Drugs., 19: 338.

Jridi, M., Boughriba, S., Abdelhedi, O., Nciri, H., Nasri, R., Kchaou, H., et al. (2019). Investigation of physicochemical and antioxidant properties of gelatin edible film mixed with blood orange (Citrus sinensis) peel extract. Food Packaging and Shelf Life, 21, 100342.

Lin, L., Regenstein, J. M., Lv, S., Lu, J., & Jiang, S. (2017). An overview of gelatin derived from aquatic animals: Properties and modification. Trends in Food Science & Technology, 68, 102–112.

Mingkang Jiang., Shaoyang Liu. and Yifen Wang., 2011. Effects of Antimicrobial Coating from Catfish Skin Gelatin on Quality and Shelf Life of Fresh White Shrimp (Penaeus vannamei). J. food science., 76(3); M204-M209.

Najafian, L. and Babji, A. S., 2012. A review of fish-derived antioxidant and antimicrobial peptides: Their production, assessment, and applications. Peptides., 33: 178–185.

Qiang, T., Chen, L., Yan, Z., & Liu, X. (2019). Evaluation of a novel collagenous matrix membrane cross-linked with catechins catalyzed by laccase: A sustainable biomass. Journal of Agricultural and Food Chemistry, 67(5), 1504–1512.

Rajeswari, C., Padmavathy, P. and Aanand, S., 2018. Composting of fish waste: A review. Int. J. Applied Res., 4(6): 242-249.

Rennie, T. J. and Sunjka, P. S. 2018. Modified atmosphere for storage, transportation, and packaging. In: Novel Postharvest Treatments of Fresh Produce (ed. Pareek, S), CRC Press/Taylor and Francis Group: Boca Raton, FL, USA. pp. 433–480

Rocha, M.D.; Loiko, M.R.; Gautério, G.V.; Tondo, E.C.; Prentice, C. Influence of Heating, Protein and Glycerol Concentrations of Film-Forming Solution on the Film Properties of Argentine Anchovy (Engraulis anchoita) Protein Isolate. J. Food Eng. 2013, 116, 666–673

Romani VP, Prentice-Hernández C, Martins VG. 2017. Active and sustainable materials from rice starch, fish protein and oregano essential oil for

food packaging. Industrial Crops and Products 97 : 268–274

Sánchez-Ortega, I., García-Almendárez, B. E., Santos-López, E. M., Amaro-Reyes, A., Barboza-Corona, J. E. and Regalado, C., 2014. Antimicrobial edible films and coatings for meat and meat products preservation. The Sci World J., 2014: 1–18.

Shahbazi, Y. (2017). The properties of chitosan and gelatin films incorporated with ethanolic red grape seed extract and *Ziziphora clinopodioides* essential oil as biodegradable materials for active food packaging. International Journal of Biological Macromolecules, 99, 746–753.

Sionkowska, A., Michalska-Sionkowska, M., & Walczak, M. (2020). Preparation and characterization of collagen/hyaluronic acid/chitosan film crosslinked with dialdehyde starch. International Journal of Biological Macromolecules, 149, 290–295.

Suderman, N., Isa, M. I. N., & Sarbon, N. M. (2018). The effect of plasticizers on the functional properties of biodegradable gelatin-based film: A review. Food Bioscience, 24, 111–119.

Suurs, P., & Barbut, S. (2020). Collagen use for co-extruded sausage casings – a review. Trends in Food Science & Technology, 102, 91–101.

Undiganalu Gangadharappa Yathisha., Sneha Vaidya. and Mamatha Bangera Sheshappa., 2022. Functional Properties of Protein Hydrolyzate from Ribbon Fish (Lepturacanthus Savala) as Prepared by Enzymatic hydrolysis. Int. J. Food Properties., 25(1): 187–203.

* * * * * * * * *