Scientific Papers. Series D. Animal Science. Vol. LXVIII, No. 1, 2025
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

FUNCTIONAL EFFECTS OF VEGETABLE BIOINGREDIENTS IN FISH-BASED PRODUCTS: A SYSTEMATIC REVIEW

Elena-Iuliana FLOCEA, Ioana GUCIANU, Diana-Romina MANOLIU, Bianca-Georgiana ANCHIDIN, Marius-Mihai CIOBANU, Paul-Corneliu BOIȘTEANU

"Ion Ionescu de la Brad" Iasi University of Life Sciences, 3 Mihail Sadoveanu Alley, 700490, Iasi, Romania

Corresponding author email: marius.ciobanu@iuls.ro

Abstract

This systematic review analyzes the scientific literature on the functional effects of vegetable bioingredients in fish products, exploring the mechanisms by which they may influence food quality and health. Studies have highlighted the synergy between vegetable components, such as polyphenols, flavonoids, omega-3 fatty acids and antioxidants, proteins, fatty acids and nutrients in fish, which may lead to improved nutritional profile and reduced risks associated with chronic diseases. The research also suggests that the integration of these vegetable bioingredients into fish products may enhance the bioavailability of nutrients, have antioxidant and anti-inflammatory effects and promote a better balance of intestinal microbiota. The conclusions of this review highlight the potential of functional fish products enriched with plant bioingredients to contribute to the prevention and management of various diseases, providing important support for the development of innovative and sustainable functional foods.

Key words*: fish-based products, sustainable functional foods, vegetable bioingredients.*

INTRODUCTION

Incorporating plant bio-ingredients into fish products can significantly improve their nutritional profile and shelf life. Various studies have shown that mixing fish with plant-based ingredients not only improves the nutritional content but also extends the shelf life of the product. The addition of orange-fleshed sweet potato to fish powder increased the level of beta-carotene from 876.12 to 3182.4 µg/100 g, significantly increasing the vitamin A content (Mekonnen & Aychiluhm, 2024). Using oyster mushrooms and seaweeds such as nori and kombu, which are rich in protein and umami flavor, creates a fish analog that mimics the nutritional profile of fish (Patil et al., 2023). The use of natural additives such as seaweeds and polysaccharides has been shown to reduce lipid oxidation and moisture loss in fish products, thereby extending shelf life (Vijayan et al., 2021; Jannat-Alipour et al., 2019). Fish products enriched with plant ingredients have demonstrated acceptable sensory attributes and maintained their quality over extended periods, with some formulations remaining safe for consumption for up to 90 days (Mekonnen & Aychiluhm, 2024; Jannat-Alipour et al., 2019). In contrast, although plant bioingredients can improve fish products, there may be challenges in terms of consumer acceptance and sensory characteristics, particularly in terms of maintaining the traditional taste and texture of fish. This highlights the need for careful formulation and testing to ensure market viability.

MATERIALS AND METHODS

The systematic review was conducted by consulting the major scientific databases Google Scholar, Web of Science, Scopus and Science Direct from May 2024 to May 2025. The search targeted relevant studies on the effects of plant bioingredients in fish-based food products. The following keyword combinations were used: fish, fish products, fish consumption, nutritional values, plant bioingredients, antioxidant activity, and antimicrobial activity.

Selection process:

1. Elimination of duplicate articles;
2. Evaluation of title and abstract;
3. Full text analysis;
4. Application of inclusion/exclusion criteria;
5. Quality assessment with Risk of Bias Tool.

The inclusion and exclusion criteria used for the selection of studies are presented in Table 1. These criteria were applied to ensure the reviewed literature's relevance, quality, and scientific validity.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Experimental or observational studies on fish products	Studies not on fish-based food products
Articles investigating the effects of plant bioingredients	Papers not assessing clear functional effects of plant bioingredients
Articles published in peer-reviewed journals	Articles without peer-review
Published in English	Published in other languages
Period: 2015-2025	Published before 2015 (with justified exceptions)

The stages of the study selection process, following the PRISMA guidelines, are summarized in Table 2.
Each step of the screening and eligibility assessment is shown along with the corresponding number of articles.

Table 2. Stages of the study selection process according to the PRISMA guidelines - tabular presentation

Stage	Number of articles
Articles identified	100
Duplicates removed	20
Remain after duplication	80
Excluded by title/abstract	21
Excluded after complete analysis	23
Included in the final analysis	36

Risk of bias assessment was performed using the Risk of Bias Tool for randomised controlled trials, taking into account: sequence generation, allocation concealment, blinding of participants/evaluators, data completeness, selectivity of reporting and other sources of systematic error.
The systematic review provides a clear and objective assessment of the available research on the impact of plant bioingredients on fish-based food products, identifying functional and nutritional effects, and will guide future research and industries towards the development of healthier and more sustainable food products.

RESULTS AND DISCUSSIONS

Current trends in fish-based food consumption

Fish is an important component in the daily diet of the population, due to its high content of polyunsaturated fatty acids with essential functional roles in health. With rising incomes, especially in developing countries, fish consumption has been on an upward trend, as it is perceived as a high-quality food (Chen, 2019). Forecasts suggest that by 2050, a significant proportion of the global population will belong to the upper-middle-income class, which will further support the demand for aquatic products associated with important nutritional benefits (Chen, 2019). The urbanization process is also contributing to increased fish consumption through easier access to a greater diversity of food products and increased purchasing power (Sarkodie & Owusu, 2023). Young people in developed countries are showing a growing preference for fish consumption, motivated by health benefits and concerns about the impact of meat consumption (Supartini et al., 2018). In addition, consumer orientation towards more nutritious food choices supports the global expansion of fish consumption (Sarkodie & Owusu, 2023).

Health benefits of consuming fish and fish products

Numerous studies have highlighted the high antioxidant potential of proteins extracted from fish (Gucianu et al., 2023). Chi et al. (2015) and You et al. (2010) reported significant antioxidant activities in protein hydrolysates obtained from the flesh of species such as *Katsuwonus pelamis* and *Misgurnus anguillicaudatus*. Wang et al. (2004) also showed that fish oil supplementation can stimulate the antioxidant enzyme activity of macrophages. Fish is an important source of essential nutrients for human health, with multiple proven benefits such as antioxidant, anti-inflammatory, cardiovascular, liver and neurological protection. Valuable fish components, such as proteins and polyunsaturated fatty acids (PUFAs), help prevent disease and support biological functions by regulating cell signaling pathways

(Chen et al., 2022). More than 40% of global biodiversity is made up of fish and other marine organisms, which are a valuable source of bioactive compounds essential for supporting human health. The bioactive components in fish, including lipids, proteins, vitamins, minerals and various by-products, are recognised for their therapeutic potential. In particular, the beneficial effects of fish consumption are attributed to the high content of long-chain omega-3 polyunsaturated fatty acids (PUFAS), which are easily absorbed by the body. Scientific research shows that, in addition to PUFAs, other bioactive compounds present in fish also contribute significantly to maintaining good health. According to the recommendations of the World Health Organization and the American Heart Association, it is recommended to regularly include fish in the diet (1-2 servings per week) to ensure an intake of 200-500 mg of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), readily available from fatty fish such as salmon or trout (Chiesa et al., 2016; Khalili Tilami et al., 2018; Ashraf et al., 2020).
Table 3 provides a comparative overview of the nutritional composition of three commonly consumed fish species: *Cyprinus carpio*, *Salmo salar*, and *Oncorhynchus mykiss*. The data include energy content, macronutrient distribution, essential minerals, key vitamins, and lipid profiles per 100 g of raw fish. These values, collected from multiple reliable sources, underline the nutritional diversity among species and support the role of fish as a valuable component of a balanced diet.

Table 3. Comparative table of nutritional values (per 100 g raw fish)

Energy values and macronutrients		Species			References
		Cyprinus carpio	*Salmo salar*	*Oncorhynchus mykiss*	
Energy		127 kcal	208 kcal	119 kcal	Karimian-Khosroshahi et al., 2016; Marcu et al., 2010; Vranić et al., 2011; Esaiassen et al., 2022; Rebolé et al., 2015; Skibniewska et al., 2013; USDA, 2023; ANSES, 2020
Proteins		17.8 g	20.4 g	20.1 g	
Carbohydrate		0	0	0	
Minerals	Calcium	19 mg	9 mg	20 mg	
	Iron	1 mg	0.8 mg	0.7 mg	
	Phosphor	210 mg	200 mg	220 mg	
	Magnesium	30 mg	27 mg	25 mg	
	Potasiu	290 mg	370 mg	321 mg	
	Sodium	65 mg	59 mg	51 mg	
Vitamins	Vitamin D	1.5 µg	9 µg	7.5 µg	
	Vitamin B12	2.2 µg	3.2 µg	4.5 µg	
	Vitamin B3	3.5 µg	7.9 µg	5.8 µg	
Fats	Saturated fatty acids	1.3 g	3.1 g	0.9 g	
	Fatty acids Omega 3	0.4-0.8 g	2.6 g	0.9-1.3 g	
	Cholesterol	70 mg	55 mg	59 mg	

EuroFIR AISBL (accessed 01.02.2025).

Valorization of fish in the development of functional food products

The integration of fish products and by-products into various food systems is a promising strategy for the development of functional foods with significant benefits for consumers. This approach contributes to meeting the nutritional requirements of vulnerable population groups, especially in the current context marked by the increased incidence of non-communicable diseases and the challenges posed by global health crises (Pateiro et al., 2021; Gucianu et al., 2024). A relevant example is the valorisation of waste from the processing of rohu fish (*Labeo rohita*), from which protein isolates were extracted and subsequently incorporated into pangasius sausages (*Pangasius pangasius*). The study demonstrated that the addition of the isolates, particularly at a level of 250 g kg^{-1}, led to an improvement in the nutritional value and some physico-chemical properties of the final product without significantly compromising sensory acceptability (Surasani et al., 2022).
Also, the use of fish by-products such as tuna and lobster in the formulation of pasta has

resulted in functional products with superior nutritional profiles. Comparative analysis of these pastes revealed significant differences in fatty acid content, texture and sensory properties. Although pasta with tuna by-product concentrate showed a higher nutritional value, it was found that reducing the tuna content is necessary to optimise sensory characteristics (Ainsa et al., 2021). In addition to by-product valorisation, fish and crustacean-derived enzymes, especially transglutaminases, also offer sustainable alternatives to commercial enzymes used in the food industry. They are characterised by their low temperature activity, thermal lability, high yields and low costs, representing innovative solutions to improve food quality and functionality (Zhang & Simpson, 2020). In addition, a standardised protocol has been developed for the industrial production of fermented fish products based on sturgeon meat (*Acipenser sinensis*), which involves salting, drying, fermentation with *Saccharomyces cerevisiae*, vacuum-packing and sterilisation. The final product obtained is characterised by a favourable sensory profile: rich aroma, reduced undesirable odours, moderate salt content, pleasant texture and attractive colour. Due to the versatility of the method, it applies to both marine and freshwater fish, providing a practical solution for the realisation of long shelf-life fermented snacks (Yang et al., 2019). Last but not least, the addition of cod liver oil, in emulsified or gelled forms, in combination with green tea extract, has demonstrated a positive impact on the technological properties of silver carp (*Hypophthalmichthys molitrix*) sausages. In particular, the gelled emulsion is an effective delivery system of omega-3 fatty acids, contributing to the improvement of the omega-6/omega-3 ratio and the maintenance of product quality during cold storage (Pourashouri et al., 2020). Fish products have a short shelf-life due to their high polyunsaturated fatty acid content and lack of endogenous antioxidants, making them vulnerable to oxidation and microbial contamination, and more effective and natural preservation methods are needed to maintain their quality (Gutiérrez-del-Río et al., 2021). Natural polyphenolic compounds, due to their antioxidant and antimicrobial properties, are a safe and effective alternative to synthetic additives for the prevention of chemical and microbiological deterioration of fish and fish products, helping to maintain their quality during processing and storage (Rathod et al., 2021). The use of natural ingredients with biologically active properties becomes essential to support the functionality of fish-based food products and extend their shelf life. In this context, bio-ingredients of plant origin, recognized for their antioxidant and antimicrobial activity, offer promising solutions from both a technological and nutritional point of view.

The role of plant bioingredients in the sensory, oxidative and microbiological protection of functional fish-based foods

The integration of fish bioactive compounds in the formulation of functional food products is a promising research direction aiming at optimizing the nutritional value of modern diets. Effective preservation strategies, preferably based on natural antioxidants and antimicrobial ingredients, need to be used to ensure the stability of these products and to prolong their shelf life, and can combat contaminants that may come from animal feed (Ciobanu et al., 2024; Matei et al., 2024; Anchidin et al., 2023). In this regard, bioingredients of plant origin have gained increased interest due to their efficiency in inhibiting oxidative and microbial processes, without compromising food safety or sensory acceptability from the consumers' perspective (Ciobanu et al., 2024; Ciobanu et al., 2025; Manoliu et al., 2024). Combining valuable animal resources, such as bioactive fish compounds, with functional plant extracts thus provides an integrated framework for the development of sustainable, safe and innovative food products. Perceptions of the healthiness of foods play a key role in product choice, with health-motivated consumers more likely to seek information or pay attention to cues that allow them to assess the nutritional benefits of available food options (Mitterer-Daltoé et al., 2014; Ciobanu et al., 2024). Phytocompounds, in particular those of the polyphenol class, have a high potential in technological applications related to fish products, contributing to their oxidative

stabilisation and shelf-life extension. Citrus peels, due to their high content of phenolic acids and flavonoids, are recognised for their remarkable antioxidant activity, often superior to synthetic antioxidants. Similarly, the use of extracts from cabbage leaves (*Brassica oleracea* var. *capitata* L.) and banana peels (*Musa* sp. L.) in fish-based food formulations has shown a significant improvement in oxidative stability. Phenolic antioxidants from these plant sources neutralise free radicals resulting from lipid oxidation, thus helping to reduce degradation processes and maintain the sensory characteristics of the final product (Gutiérrez-del-Río et al., 2021).

Ali et al. (2019) used a Box-Behnken experimental design to optimize the extraction parameters to maximize the yield of total phenolic compounds (TPCs) from plant by-products such as cabbage leaves and banana peels. The obtained extracts were chemically characterised and subsequently incorporated at concentrations of 0.5%, 1% and 1.5% into fish meat products to evaluate the influence on lipid oxidative stability and sensory properties during storage at refrigerated (9 days) and frozen (60 days) temperatures. In the context of current food safety concerns, recent research is increasingly focusing on the use of natural preservatives as an alternative to synthetic additives. By-products resulting from vegetable processing are promising sources of natural antioxidants, the use of which in the food industry can generate economic benefits for producers and improve the nutritional value of consumer products (Boișteanu et al., 2025).

Figure 1 illustrates the main natural antioxidant compounds evaluated in fish-based food products, along with their reported effects. This graphical representation, adapted from Gutiérrez-del-Río et al. (2021), highlights the functional roles of various plant-derived bioactive compounds in enhancing the oxidative stability and overall quality of fish products.

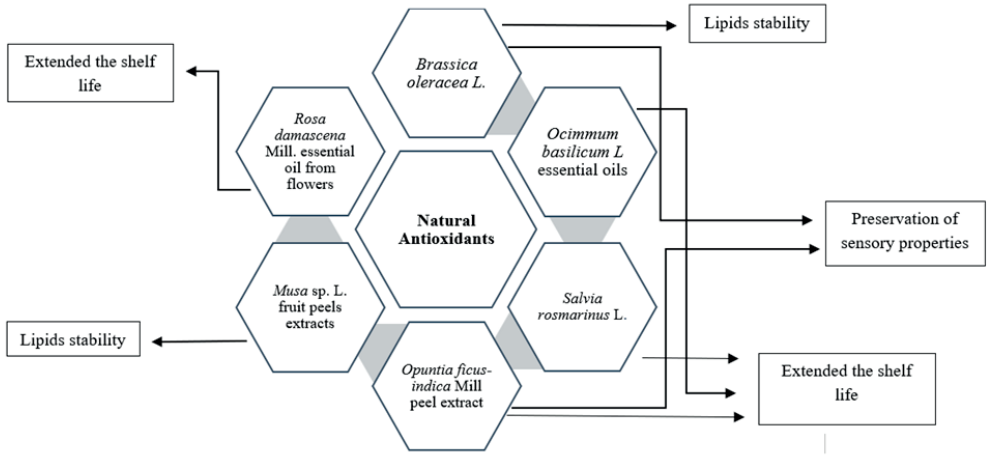

Figure 1. Graphical representation of the main natural antioxidant compounds tested in fish food products and their effects according to Gutiérrez-del-Río et al. (2021)

Plant bioactive compounds, such as polyphenols, flavonoids and tannins, exert a protective role in the food matrix of fish products, in particular through mechanisms that inhibit lipid and protein oxidation. At the molecular level, these compounds act as electron or hydrogen atom donors, neutralising free radicals (such as the peroxyl radical ROO- or hydroxyl radical OH-), which are responsible for the initiation and propagation of unsaturated fatty acid oxidation chains in fish. Polyphenols bind to free radicals formed during oxidative stress and form stable species, stopping the chain reactions of lipid peroxidation. Flavonoids can chelate transition metal ions (Fe^{2+}, Cu^{2+}), which catalyse the Fenton and Haber-Weiss reactions responsible

for the generation of highly reactive hydroxyl radicals. Tannins form complexes with proteins and protect them from oxidative degradation, thus maintaining the texture and nutritional value of the product (Deng et al., 2025; Lipşa et al., 2024).

To highlight the functional potential of various plant-based bioingredients in fish-based products, several studies have investigated their antioxidant and antimicrobial properties. Table 4 below summarizes key findings regarding the concentrations used, types of fish products tested, and the observed preservation effects. These natural extracts, often applied in small percentages, have shown promising results in enhancing shelf life and maintaining product quality, making them suitable candidates for clean-label reformulations.

Table 4. Functional effects of vegetable bioingredients used in fish-based products

Vegetable bioingredient	Concentration %	Fish food product	Observed effect	Ref.
Salvia rosamarinus extract	0.02	Fish Patties	Delayed lipid oxidation reduced microbiological spoilage during cold storage.	Martínez et al., 2019
Punica granatum extract	0.02	Fish Patties	Significant antioxidant and antimicrobial activity, contributing to extended shelf life.	Martínez et al., 2019
Olea europaea extract (hydroxytyrosol)	0.02	Fish Patties	Reduced lipid oxidation and microbiological spoilage, extending product shelf life.	Martínez et al., 2019
Nymphaea nouchali extract	10.0(w/v)*	Frozen Tilapia Fillets	Shelf-life extension through inhibition of lipid oxidation, microbial growth, and maintenance of sensory quality.	Dulal et al., 2023
Sambucus nigra extract	0.005-0.01	Salmon Burgers	Antioxidant and antimicrobial effects help maintain product quality during storage.	Jonušaite et al., 2021

*Extract types: water (0E), 50%, 75%, and 100% ethanol

In addition to these antioxidant functions, many phenolic compounds also possess antimicrobial properties, affecting the membrane permeability of bacteria or interfering with their metabolism, contributing to shelf-life extension. Phenolic compounds (e.g. flavonoids, phenolic acids) can interact with bacterial membrane lipids, leading to disruption of the lipid bilayer structure, causing loss of membrane integrity. Increased membrane permeability allows essential ions (K^+, H^+) and other metabolites to escape. The decrease in membrane potential, affects the functioning of ion pumps and active transport, and in Gram-negative bacteria, the compounds can destabilize the lipopolysaccharide layer (LPS). This leads to a loss of protons and ATP, affecting the energy of the bacterial cell. Some phenolic compounds act on essential bacterial enzymes, may inhibit enzymes involved in glycolysis, the Krebs cycle or the respiratory chain, and bind sulfhydryl (-SH) groups of proteins or interfere with metal groups (Fe, Cu) in redox enzymes. They act as pro-oxidising agents in the bacterial cell, generating reactive oxygen species (ROS) that cause oxidative stress. Phenolic compounds can interfere with DNA, blocking replication or transcription, inhibit ribosome activity, affecting protein synthesis, and in some cases, phenols can form chelates with metal ions required for replication processes or DNA stability. Some phenolic compounds induce an internal oxidative stress in the bacterial cell through redox imbalance. This may activate the apoptotic cascade in some sensitive bacteria. All these mechanisms lead to the cleavage of microorganisms, stopping bacterial multiplication and slowing down the spoilage of food products by prolonging shelf life (Lipşa et al., 2024; McGurrin et al., 2025).

CONCLUSIONS

The findings of this systematic review highlight the significant potential of functional fish products enriched with plant bio-ingredients in the context of current consumer trends towards healthy and sustainable food. The regular consumption of fish and fish products is well documented for its health benefits due to its omega-3 fatty acids, high-quality protein and essential micronutrients. The integration of plant bioingredients in these products not only capitalizes on fish resources through the development of innovative functional foods but

also contributes to protection against oxidation and microbiological contamination, thus improving food safety and sustainability. The synergy between bioactive plant compounds (such as polyphenols and flavonoids) and fish-specific compounds enhances health benefits by promoting nutrient bioavailability, gut microbiota balance and reducing the risk of chronic diseases. These results support the development of advanced functional food products with high nutritional value and a positive impact on public health.

REFERENCES

Ainsa, A., Honrado, A., Marquina, P.L., Roncalés, P., Beltrán, J.A., & Calanche, M.J.B. (2021). Innovative Development of Pasta with the Addition of Fish By-Products from Two Species. *Foods*, *10*(8), 1889. https://doi.org/10.3390/foods10081889

Ali, M., Imran, M., Nadeem, M., Khan, M. K., Sohaib, M., Suleria, H. A. R., & Bashir, R. (2019). Oxidative stability and Sensoric acceptability of functional fish meat product supplemented with plant-based polyphenolic optimal extracts. *Lipids in health and disease*, *18*, 1–16. https://doi.org/10.1186/s12944-019-0982-y

Anchidin, B. G., Manoliu, D. R., Ciobotaru, C. M., Ciobanu, M.M., Gucianu, I., Sandu, G. A., & Boișteanu, P.C. (2023). Development of a Functional Meat Product with sea Buckthorn Oil and Analysis of Its Sensory and Physicochemical Quality. *Scientific Papers. Series D. Animal Science*, 67(1), 484–496.

ANSES (2020). *Table de composition nutritionnelle des aliments Ciqual 2020*. Maisons-Alfort, FR: Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail. https://ciqual.anses.fr/

Ashraf, S.A., Adnan, M., Patel, M., Siddiqui, A.J., Sachidanandan, M., Snoussi, M., & Hadi, S. (2020). Fish-Based Bioactives as Potent Nutraceuticals: Exploring the Therapeutic Perspective of Sustainable Food from the Sea. *Marine Drugs*, *18*, 265. https://doi.org/10.3390/md18050265

Boișteanu, P. C., Anchidin, B. G., & Ciobanu, M. M. (2025). Exploring Sensory Attributes in Spinach-and Offals-Filled Chicken Roulades: An Empirical Analysis. *Foods, 14*(2), 303. https://doi.org/10.3390/foods14020303

Chen, J., Jayachandran, M., Bai, W., & Xu, B. (2022). A critical review on the health benefits of fish consumption and its bioactive constituents. *Food Chemistry*, *369*, 130874. https://doi.org/10.1016/j.foodchem.2021.130874

Chen, O. L. (2019). The big picture: future global seafood markets. *Predicting Future Oceans*, 241–248. https://doi.org/10.1016/B978-0-12-817945-1.00022-8

Chi, C. F., Hu, F. Y., Wang, B., Li, Z. R., & Luo, H. Y. (2015). Influence of amino acid compositions and peptide profiles on antioxidant capacities of two protein hydrolysates from skipjack tuna (*Katsuwonus pelamis*) dark muscle. *Marine Drugs*, *13*(5), 2580–2601. https://doi.org/10.3390/md13052580

Chiesa, G., Busnelli, M., Manzini, S., & Parolini, C. (2016). Nutraceuticals and bioactive components from fish for dyslipidemia and cardiovascular risk reduction. *Marine drugs*, *14*(6), 113. https://doi.org/10.3390/md14060113

Ciobanu, M. M., Flocea, E. I., & Boișteanu, P. C. (2024). The Impact of Artificial and Natural Additives in Meat Products on Neurocognitive Food Perception: A Narrative Review. *Foods*, *13*(23), 3908. https://doi.org/10.3390/foods13233908

Ciobanu, M. M., Manoliu, D. R., Ciobotaru, M. C., Flocea, E. I., & Boișteanu, P. C. (2025). Dietary Fibres in Processed Meat: A Review on Nutritional Enhancement, Technological Effects, Sensory Implications and Consumer Perception. *Foods*, *14*(9), 1459. https://doi.org/10.3390/foods14091459

Deng, H., Zhang, W., Ramezan, Y., Riahi, Z., Khan, A., & Huang, Z. (2025). Antibacterial and antioxidant plant-derived aldehydes: A new role as cross-linking agents in biopolymer-based food packaging films. *Comprehensive Reviews in Food Science and Food Safety*, *24*(1), e70089. https://doi.org/10.1111/1541-4337.70089

Dulal, M. A., Jahan, I., Rasul, M. G., Islam, M. R., Khan, M., & Shah, A. A. (2023). Antioxidant and antimicrobial potential of water lily extracts and their effects on the quality of frozen Nile tilapia (*Oreochromis niloticus*) fillets. *Food Science & Nutrition*, *11*(1), 535–544. https://doi.org/10.1002/fsn3.3084

Esaiassen, M., Jensen, T. K., Edvinsen, G. K., Otnæs, C. H., Ageeva, T. N., & Mæhre, H. K. (2022). Nutritional value and storage stability in commercially produced organically and conventionally farmed Atlantic salmon (*Salmo salar* L.) in Norway. *Applied Food Research*, *2*(1), 100033. https://doi.org/10.1016/j.afres.2021.100033

EuroFIR AISBL. (accessed 01.05.2024). *EuroFIR FoodEXplorer – Online food composition database*. Brussels, BE. https://www.eurofir.org/foodexplorer/

Gucianu, I., Anchidin, B. G., Manoliu, D. R., Ciobotaru, M. C., Boișteanu, P. C., Postolache, A. N., & Ciobanu, M. M. (2023). Smoking Temperature Characteristics and Influence of Quality Indicators on Phytophagus Fillet (*Hypophthalmichthys molitrix*). *Scientific Papers. Series D. Animal Science, 66*(2), 512–516.

Gucianu, I., Lipșa, F. D., Anchidin, B. G., Flocea, E.-I., Boișteanu, P. C., & Ciobanu, M. M. (2024). Combating food waste by making a functional product from a slaughterhouse by product and profiling its nutritional value. *Scientific Papers. Series D. Animal Science*, *67*(1), 457–464.

Gutiérrez-del-Río, I., López-Ibáñez, S., Magadán-Corpas, P., Fernández-Calleja, L., Pérez-Valero, Á., Tuñón-Granda, M., Miguélez, E. M., Villar, C. J., & Lombó, F. (2021). Terpenoids and Polyphenols as Natural Antioxidant Agents in Food Preservation. *Antioxidants*, *10*(8), 1264. https://doi.org/10.3390/antiox10081264

Jannat-Alipour, H., Rezaei, M., Shabanpour, B., Tabarsa, M., & Rafipour, F. (2019). Addition of seaweed powder and sulphated polysaccharides on shelf-life extension of functional fish surimi restructured product. *Journal of Food Science and Technology-Mysore*, *56*(8), 3777–3789. https://doi.org/10.1007/s13197-019-03846-y

Jonušaite, K., Venskutonis, P. R., Martínez-Hernández, G. B., Taboada-Rodríguez, A., Nieto, G., López-Gómez, A., & Marín-Iniesta, F. (2021). Antioxidant and Antimicrobial Effect of Plant Essential Oils and *Sambucus nigra* Extract in Salmon Burgers. *Foods*, *10*(4), 776. https://doi.org/10.3390/foods10040776

Karimian-Khosroshahi, N., Hosseini, H., Rezaei, M., Khaksar, R., & Mahmoudzadeh, M. (2016). Effect of different cooking methods on minerals, vitamins, and nutritional quality indices of rainbow trout (*Oncorhynchus mykiss*). *International Journal of food properties*, *19*(11), 2471–2480. https://doi.org/10.1080/10942912.2015.1039028

Khalili Tilami, S., & Sampels, S. (2018). Nutritional value of fish: lipids, proteins, vitamins, and minerals. *Reviews in Fisheries Science & Aquaculture*, *26*(2), 243–253. https://doi.org/10.1080/23308249.2017.1399104

Lipșa, F. D., Stoica, F., Rațu, R. N., Veleșcu, I. D., Cârlescu, P. M., Motrescu, I., Usturoi, M. G., & Râpeanu, G. (2024). Red Onion Peel Powder as a Functional Ingredient for Manufacturing Ricotta Cheese. *Foods, 13*(2), 182. https://doi.org/10.3390/foods13020182

Manoliu, D. R., Ciobanu, M.M., Ciobotaru, M.C., Anchidin, B.G., & Boișteanu P.C. (2024). The impact of fruit fiber on meat products: a mini review. *Scientific Papers. Series D. Animal Science*, *67*(1), 481–589.

Marcu, A. D., Nichita, I. L., Nicula, M. A., Marcu, A. D., & Kelciov, B. (2010). Studies regarding the meat quality of the specie *Cyprinus carpio*. *Scientific Papers: Animal Science and Biotechnologies*, *43*(2), 280–283. https://www.usab-tm.ro/vol10bMV/45_vol10b.pdf

Martínez, L., Castillo, J., Ros, G., & Nieto, G. (2019). Antioxidant and antimicrobial activity of rosemary, pomegranate and olive extracts in fish patties. *Antioxidants, 8*(4), 86. https://doi.org/10.3390/antiox8040086

Matei, M., Petrescu, S. I., Mădescu, B. M., Lăpușneanu, D. M., Simeanu, D., Boișteanu, P. C., & Pop, I. M. (2024). The Impact of Feed Management Technologies on Mineral Oil Hydrocarbons (MOH) Contamination: A Comparative Farm Level Approach. *Agriculture, 14*(11), 2008. https://doi.org/10.3390/agriculture14112008

McGurrin, A., Suchintita Das, R., Soro, A. B., Maguire, J., Flórez Fernández, N., Dominguez, H., Torres, M. D., Tiwari, B. K., & Garcia-Vaquero, M. (2025). Antimicrobial activities of polysaccharide-rich extracts from the Irish seaweed *Alaria esculenta*, generated using green and conventional extraction technologies, against foodborne pathogens. *Marine Drugs*, *23*(1), 46. https://doi.org/10.3390/md23010046

Mekonnen, H. B., & Aychiluhm, T. B. (2024). Enhancement of nutritional quality and shelf life of fish products (powder & chapatti) via fortifying with orange-fleshed sweet potato. *Food Science & Nutrition*, *12*(1), 298–312. https://doi.org/10.1002/fsn3.3760

Mitterer-Daltoé, M. L., Queiroz, M. I., Fiszman, S., & Varela, P. (2014). Are fish products healthy? Eye tracking as a new food technology tool for a better understanding of consumer perception. *LWT-Food Science and Technology*, *55*(2), 459–465. https://doi.org/10.1016/j.lwt.2013.10.013

Pateiro, M., Domínguez, R., Varzakas, T., Munekata, P. E., Movilla Fierro, E., & Lorenzo, J. M. (2021). Omega-3-rich oils from marine side streams and their potential application in food. *Marine Drugs*, *19*(5), 233. https://doi.org/10.3390/md19050233

Patil, S., Urankar, D., Bhalerao, P. P., Dabade, A., Bhushette, P., & Sonawane, S. K. (2023). Development of plant-based fish analog: Optimization using D-optimal mixture design and fuzzy analysis, Characterization and shelf life study. *Food Chemistry Advances, 3*, 100485. https://doi.org/10.1016/j.focha.2023.100485

Pourashouri, P., Shabanpour, B., Kordjazi, M., & Jamshidi, A. (2020). Characteristic and shelf life of fish sausage: fortification with fish oil through emulsion and gelled emulsion incorporated with green tea extract. *Journal of the Science of Food and Agriculture*, *100*(12), 4474–4482. https://doi.org/10.1002/jsfa.10488

Rathod, N. B., Ranveer, R. C., Benjakul, S., Kim, S. K., Pagarkar, A. U., Patange, S., & Ozogul, F. (2021). Recent developments of natural antimicrobials and antioxidants on fish and fishery food products. *Comprehensive Reviews in Food Science and Food Safety*, *20*(4), 4182–4210. https://doi.org/10.1111/1541-4337.12787

Rebolé, A., Velasco, S., Rodríguez, M. L., Treviño, J., Alzueta, C., Tejedor, J. L., & Ortiz, L. T. (2015). Nutrient content in the muscle and skin of fillets from farmed rainbow trout (*Oncorhynchus mykiss*). *Food Chemistry*, *174*, 614-620. https://doi.org/10.1016/j.foodchem.2014.11.072

Sarkodie, S. A., & Owusu, P. A. (2023). Assessment of global fish footprint reveals growing challenges for sustainable production and consumption. *Marine Pollution Bulletin*, *194*, 115369. https://doi.org/10.1016/j.marpolbul.2023.115369

Skibniewska, K. A., Zakrzewski, J., Kłobukowski, J., Białowiąs, H., Mickowska, B., Guziur, J., Walczak, Z., & Szarek, J. (2013). Nutritional value of the protein of consumer carp *Cyprinus carpio* L. *Czech Journal Food Science, 31*(4), 313–317. doi: 10.17221/337/2012-CJFS.

Supartini, A., Oishi, T., & Yagi, N. (2018). Changes in Fish Consumption Desire and Its Factors: A Comparison Between the United Kingdom and Singapore. *Foods*, *7*(7), 97. https://doi.org/10.3390/foods7070097

Surasani, V. K. R., Raju, C. V., Sofi, F. R., & Shafiq, U. (2022). Utilization of protein isolates from rohu (*Labeo rohita*) processing waste through

incorporation into fish sausages; quality evaluation of the resultant paste and end product. *Journal of the Science of Food and Agriculture*, *102*(3), 1263–1270. https://doi.org/10.1002/jsfa.11464

United States Department of Agriculture. (2023). *FoodData Central*. Washington, USA: U.S. Department of Agriculture, Agricultural Research Service. https://fdc.nal.usda.gov/

Vijayan, A., Sivaraman, G. K., Visnuvinayagam, S., & Mothadaka, M. P. (2021). *Role of Natural Additives on Quality and Shelf Life Extension of Fish and Fishery Products*. London, UK: IntechOpen. doi: 10.5772/intechopen.99436

Vranić, D., Đinović-Stojanović, J., & Spirić, A. (2011). Rainbow trout (*Oncorhynchus mykiss*) from aquaculture–meat quality and importance in the diet. *Scientific journal "Meat Technology"*, *52*(1), 122–133.

Wang, H. H., Hung, T. M., Wei, J., & Chiang, A. N. (2004). Fish oil increases antioxidant enzyme activities in macrophages and reduces atherosclerotic lesions in apoE-knockout mice. *Cardiovascular research*, *61*(1), 169–176. https://doi.org/10.1016/j.cardiores.2003.11.002

Yang, F., Zhu, L. L., Diao, Y. D., Gao, P., Yu, D. W., Yu, P. P., Jiang, Q. X., Xu, Y. S., Xia, W. S., & Zhan, X. B. (2019). Preparation of High-Quality Fermented Fish Product. *Journal of visualized experiments,* 150, 1-8. https://doi.org/10.3791/60265

You, L., Zhao, M., Regenstein, J. M., & Ren, J. (2010). Purification and identification of antioxidative peptides from loach (*Misgurnus anguillicaudatus*) protein hydrolysate by consecutive chromatography and electrospray ionization-mass spectrometry. *Food Research International*, *43*(4), 1167–1173. https://doi.org/10.1016/j.foodres.2010.02.009

Zhang, Y., & Simpson, B. K. (2020). Food-related transglutaminase obtained from fish/shellfish. *Critical reviews in food science and nutrition*, *60*(19), 3214–3232. https://doi.org/10.1080/10408398.2019.1681357