Chapter

Role of Natural Additives on Quality and Shelf Life Extension of Fish and Fishery Products

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Abstract

Fish and fishery products have drawn greater attention due to their high nutritional value owing to the presence of cheap superior quality proteins, essential fatty acids, and macro and micronutrients. But higher water content, non- protein nitrogen, and post mortem pH (6–7) in fish favor rapid spoilage by autolysis or putrefaction, and can result in health risk as well as economic loss. Moreover, the quality of fish is affected by species, harvesting season, handling and method of processing. Thus, application of food additives become necessary to maintain the shelf life, nutritional content, texture and flavor of the raw material as well as processed products. Considerable research is being done on applications of natural additives after the emergence of the concept 'Green consumerism' which resulted in decreased consumer preference for using synthetic food additives. In this background, this chapter will review the natural additives used for quality maintenance and shelf life extension of fish and fishery products.

Keywords: Spoilage, Autolysis, Putrefaction, Shelf life, Green consumerism

1. Introduction

Fish and fishery products have become increasingly popular due to their high demand and nutritional value. According to Food and Agriculture Organization (FAO), worldwide production of finfish, mollusks (mainly bivalves), and crustaceans are 54.3, 17.7, and 9.4 million tons respectively [1]. Human consumption of fish is around 88% of total production and among them, 44% consist of live, fresh, or chilled products, and 35% consist of frozen products [2]. But, among animal-derived products, fish is considered as the most perishable commodity as it contains a high amount of water, high post mortem pH (greater than 6), non-protein-nitrogen content, free amino acids, lower content of connective tissues, and presence of an osmoregulant, trimethylamine oxide (TMAO) [3]. Spoilage or the deterioration process refers to any change in the condition of food in terms of taste, smell, appearance, or texture and becomes undesirable or unacceptable for human consumption. Generally, the process involves 3 stages; rigor mortis, autolysis, and putrefaction. Rigor mortis or the muscle stiffening will last for hours (time may vary with temperature) after their catch. Subsequently softening occurs due to enzymatic or oxidative self-digestion, and completed by microbiological processes (putrefaction) [4].

Every year, chemical and microbial deterioration alone contributes 25% of gross primary product loss (agricultural and fishery products). Besides this, there are several other factors such as harvesting season, type of species, capturing method, handling, the time lag from catch to processing, method of processing, storage temperature, etc. that also influence the rate of spoilage. During spoilage, the breakdown of various components and formation of new compounds responsible for the off- flavor, off odor, discoloration, and texture damage of the fish meat takes place [5]. Therefore, certain food additives have been added to maintain the quality, and the shelf-life of fish and fishery products. The main aim is to combat microbial contamination as well as oxidation for the extension of product's shelf life. Generally, lipid oxidation leads to quality deterioration, and some of them can be detected by organoleptic evaluation, but microbial contamination especially pathogenic microorganisms mostly do not produce sensory deterioration, which act as a challenge for food safety. It emphasizes the importance of the application of antimicrobials in the preservation techniques [6]. In the case of fish and fishery products, preservation techniques draw more scientific attraction, since they represent internationally traded products. Even though many strategies have been developed to prevent chemical and microbial spoilage by chemical preservation, there is still a need for the use of natural preservatives, considering consumer safety. Thus, various researches and efforts have been made to invent more natural alternative solutions in the field of food preservation.

2. Quality changes in fish and fishery products

Fish and fishery products deteriorate rapidly as a consequence of various biochemical breakdowns and microbial activities on the chemical composition of meat. The spoilage involves autolysis or self-digestion of these compounds by digestive enzymes or by free radicals [7]. The major spoilage process is lipid degradation, which mainly occurs through oxidation or hydrolysis. The oxidation could be various types such as photo-oxidation, thermal oxidation, enzymatic oxidation, and auto-oxidation. It can also be accelerated by prooxidants within the body such as hemoglobin, myoglobin, cytochrome c, etc. The process involves the reaction of unsaturated fatty acids of triglycerides with atmospheric oxygen to form unstable primary products like free fatty acids (FFAs), dienes, and peroxides and secondary products like aldehydes, ketones, alcohols, hydrocarbons, volatile organic acids, trienes, epoxy compounds and carbonyls [8]. The process of lipid hydrolysis or lipolysis is breaking down of triglycerides into FFAs by the action of enzyme lipases. Accumulation of these FFAs stimulates protein denaturation, texture damage, and drip loss by the formation of protein-lipid cross-linkages [9]. Generally, protein denaturation in fish occurs mainly by the action of proteolytic enzymes in the muscle (cathepsins) and the intestinal tract (trypsins), which results in muscle solubilization and leads to undesirable texture damage. End products like amino acids, peptides, amines, H_2S, ammonia, indole, etc. will be formed and will all act as a medium for microbial growth. Microbial breakdown of amino acids will lead to bitterness, souring, bad odor, sliminess, etc. of the flesh [10].

For fish and fishery products, gram-negative bacteria like *Shewanella, Photobacterium, Pseudomonas, Moraxella, Acinetobacter, Flavobacterium*, Aeromonadaceae, and Vibrionaceae and the gram-positive bacteria such as *Bacillus, Micrococcus, Lactobacillus, Clostridium*, and *Corynebacterium* are considered as the major spoilers [3, 10]. The spoilage resulting in off-flavors is due to the formation of specific alcohols, aldehydes, acids, ketones, and sulfur and nitrogen compounds. One of the other major non-nitrogen compounds formed is trimethylamine (TMA) by the action of several spoilage bacteria on TMAO, an osmoregulant, present in fish (mostly marine and some freshwater fish), and cause a high (positive) redox potential (Eh) in the flesh. Under anoxic conditions, many of the spoilage bacteria utilize TMAO as a terminal hydrogen acceptor, thus allowing them to grow, and resulting in the formation of TMA. TMA reacts with lipids in the muscle to produce the off odor of low-quality fish. This could be a reason for rapid spoilage occurring in seafood than other muscle foods [11]. Thus, microbial spoilage can be determined by TMA level in the product. In the case of shrimps, at above 10°C, indole-positive organisms such as Aeromonas cause subsequent conversion of tryptophan to indole, which is associated with the off-odor of decomposition of shrimp. Thus high levels of indole in the flesh is an indicator of high temperature in the chilled storage process [12]. Clams and oysters undergo fermentative type spoilage also [13]. Generally, the microbial contamination in the fish mainly occurs through microbes associated with the habitat, invasion during processing, handling, and long-term storage. Growth of spoilers differs by habitats like freshwater or marine, temperate or tropical water, and storage or processing conditions. The microbial and chemical stability of food during processing and storage will be determined by the available water for microbial growth, called water activity (a_w). Yeast requires a_w of minimum 0.7 for their growth, and except *Staphylococcus aureus,* most bacteria require at least 0.9 a_w to grow [14]. Thus, it can be said that microbiologically stable fish product is with an a_w less than 0.6 [15]. Thus, the water content in the product should be minimum to prevent microbial spoilage. Moreover, pathogenic microbes of public health concern are also taken into consideration as they can produce hazardous toxins. Some of these are; toxin produced by *Clostridium botulinum* (botulinum toxin) in processed food, Scombrotoxin as a result of the microbial conversion of histidine to histamine. Bacteria involved in this process include *Morganella morganii, Klebsiella pneumoniae, Hafnia alvei*, *Pseudomonas putrefaciens*, and *Clostridium perfringens*. Shellfishes can accumulate various algal toxins like brevetoxins, okadaic acids, domoic acids, saxitoxins, etc., and cause serious illness to humans [16].

Another important spoilage mechanism is post-mortem nucleotide catabolism, resulting in ATP depletion and subsequent formation of hypoxanthine (Hx) (**Figure 1**). The breakdown products do not affect the safety but sensory quality undergoes some changes [17, 18]. Based on these compounds formed, the freshness can be expressed. The ratio of inosine (Ino) and Hx to total nucleotides and their

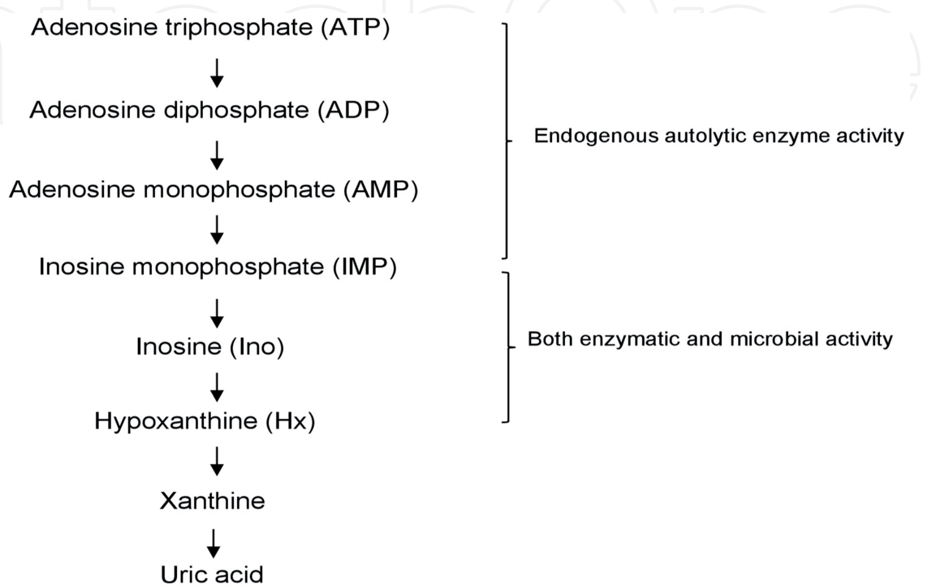

Figure 1.
Nucleotide catabolism as a result of autolysis and putrefaction.

catabolic derivatives will give the K value, an indicator of loss of freshness [19]. The ratio of Hx to the total of Inosine monophosphate (IMP), Ino, and Hx will give the H value, an indicator of Hx accumulation (bitterness), and its limit for human consumption has been suggested as 60% [20]. Another quality indicator is the F value. It is the ratio of IMP to the total of IMP, Ino, and Hx, and fish with F-value of 10% and higher is considered unacceptable [21]. Thus there is a huge need for the use of additives in the food industry. Application of food additives and low-temperature preservation leads to diminution of most of the spoilage process to a greater extent.

3. Role of chemical additives and natural alternative solutions

By definition, additives are the substances that are added to maintain or improve the safety, freshness, taste, texture, or appearance of food. Generally additives can occur in fish and fishery products during production, processing, storage, packaging, and transportation. Additives can be of two types; Synthetic or chemical, and natural additives. Some of them are listed in **Table 1**.

3.1 Chemical additives

Among chemical additives, the most common and widely used chemical is sodium chloride (NaCl). Salt drying and brining is the most traditional as well as an effective method of food preservation, and several studies have been made to explore all the preservation properties of NaCl. In Nile tilapia fillets, NaCl improved the weight and minimized drip loss [34], showed weight gain in white shrimp (*Litopenaeus vannamei*) [35], and had anti-melanotic activity along with the shelf-life extension in shrimp (*Xyphopenaeus kroyeri*) [36]. Like salt, sugar is also easily available and is a widely used additive for seafood products. Sugar treatment can significantly reduce pH value and decrease volatile bases like total volatile base nitrogen (TVB-N) [37]. It also showed a cryoprotectant action in frozen surimi (wet protein concentrate) and other products [38, 39], protection of myofibrillar protein [40], decrease the accumulation of biogenic amines in sausages and dry-cured grass carp [41, 42], and prevention of protein denaturation in minced fish meat [43]. The combination of both sugar and salt could also delay spoilage and improve many sensory qualities [37]. The product 'gravad' traditionally manufactured in Nordic countries is prepared by such a combination of sugar and salt [44]. Additives such as table salt and organic acids like acetic acid or citric acid in the Marination technique not only prevent microbial growth but also improve organoleptic properties of fish and fishery products [45]. In seafood, the addition of organic acids provides great preservative action as an antimicrobial agent. Acetic acid and lactic acid, either single-use or combination had a growth-inhibiting effect against pathogens like *Listeria monocytogenes* and *Escherichia coli* [46]. The inhibitory effect of these acids against *L. monocytogenes* was also reported from mussels [47]. Generally, the addition of citric acid showed a positive impact on TVB-N accumulation, toughness, and pH, but a negative impact on the texture and cooking yield of refrigerated shrimp. In such a case, sodium citrate helps to improve cooking yield and texture by preventing excessive pH drop [48]. Sodium or potassium lactate is also considered a good additive for seafood products. It showed shelf-life extension in minced fish products [49], antibacterial effect in sliced salmon [50], in cold-smoked salmon [51], and in catfish fillets [52].

Many other compounds, including phosphates, carbonates, and sulfites, are used as major seafood additives. Phosphate compounds especially, polyphosphates (PP) have been widely used in fish and fishery products as cryoprotectant [38],

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Additive function	Categories	Examples	Application	Reference
To maintain palatability and wholesomeness (preservatives)	Antimicrobial agents	Benzoates, Sorbates, NaCl NO_3^-, NO_2^- Organic acids, EOs	Surimi/minced fish products dried, salted or cured fish Fish fillets	[22, 23]
	Antioxidants	BHA, BHT, TBHQ, PG, Ca/Na propionate, vit E, Ascorbate, Citric acid, Erythorbic acid EOs	Fish oil Fish fillets	[24–26]
To enhance the appeal of foods	Flavor enhancers	MSG, $CaCl_2$, Citric acid, Disodium guanylate/ inosinate	Ready to cook or ready to eat products	[25]
	Sweeteners	Sucrose, lactose, glucose, fructose, glycerol, sorbitol. Acesulfame K, Aspartame, Sodium cyclamate, Saccarin, Sucralose, Neotam, Neohesperidine	Crab meat Fish fillets Marinades	[27, 28]
	Colorants	Carmine, carmosine, caramel, paprika, annatto dye Iron oxides and hydroxides, Ponceau, Cochineals, Oleoresin of turmeric, TiO_2, FD&C Yellow, Astaxanthin	Paste products, pre-cooked crustaceans, salmon substitutes, surimi, fish roe and smoked fish.	[28, 29]
	Texturizing agents; (Emulsifiers/Stabilizers/ Water-binding agents)	Polysorbates, DATEM, Agar, Alginates, Carrageenan, gum, Calcium stearate, Lecithin, Yeast, Ammonium alum,	Fish and shrimp paste/mince products, Surimi	[25, 30]
To aid in the processing	Moisture control	CaO, Calcium stearate, STPP	Processed products	[25]
	Reduce thaw drip	Na_2CO_3, SHMP, STPP, TSPP	Frozen: clams, crab, fillets, lobster, shrimp and minced fish	[31]
	Prevent cracking of glaze	Na_3PO_4, Na_2HPO_4	Frozen products	[31]
	Anticaking agents	$Ca_3(PO4)_2$, Na_2SiO_3, Ca_2SiO_4, $MgCO_3$, $Na_4P_2O_7$	Paste/minced products	[25]
	Prevent discolouration/ blackspot/browning	Na_2SO_3 4-Hexylresorcinol, EDTA	Crustaceans	[32]
	Packaging gases	O_2, CO_2, N_2, Ar, O_3, N_2O, He, SO_2, Cl	Fish and fishery products	[33]
	Cryoprotectants	PP	Paste products, fillets, Frozen crustaceans	[28]

Table 1.
Lists of additives used in fish and fishery products.

gel strength, and flavor enhancer [53], for providing higher cooking yield [31], improving weight, and reducing drip loss [34, 54], modifying texture, color, and reducing cooking loss [55–57], improving quality of fillet [58], minimizing drip loss in shrimp [59, 60], drip loss in sea robin (*Prionotus punctatus*) and pink cuskeel (*Genypterus brasiliensis*) fillet [31], and weight gain in kutum (*Rutilus frisii*) fillets [61]. Sodium hexametaphosphate (SHMP) or tripolyphosphate (STPP), or pyrophosphate- tribasic/ tetrabasic (TSPP) are the major phosphate compounds used in processing. Among carbonates, sodium carbonate (Na_2CO_3) sodium bicarbonate ($NaHCO_3$), and magnesium carbonate ($MgCO_3$) have been widely used. Weight gain is observed when white shrimp are treated with Na_2CO_3 and $NaHCO_3$ [35]. The addition of $NaHCO_3$ also provides the highest expansion volume for yellow pike conger crackers [62]. Sulfites have been widely used as additives due to their desirable technical properties like preventing melanosis or discoloration. The most predominant sulfiting agent is sodium sulfite used to prevent melanosis in crustaceans like shrimp, lobster, crab, crayfish, etc. [32]. Nitrite is another chemical commonly used as an antimicrobial agent, and effective against *C. botulinum* and its toxin production [63]. A combination of nitrite and sorbic acid would also give the best result as it can inhibit most yeasts. A combination of sorbic acid with benzoic acid could preserve brined shrimp [64]. Moreover, additives such as flavor enhancers, sweeteners, colorants, etc. are used to enhance the appeal of the food. Monosodium glutamate (MSG), calcium chloride ($CaCl_2$), and Disodium guanylate/ inosinate are the major flavor enhancers. Commonly used sweetening agents are saccharin, sucralose, glycerol, acesulfame potassium, aspartame, sodium cyclamate, neotam, and neohesperidine. Widely used colorants include carmine, carmosine, caramel, paprika, annatto dye, iron oxides and hydroxides, ponceau, cochineals, titanium dioxide (TiO_2), FD&C Yellow, and astaxanthin (**Table 1**). Butylated hydroxyl toluene (BHT), butylated hydroxyanisole (BHA), tertbutylhydroquinone (TBHQ), propyl gallate (PG), and sodium acetate are widely used synthetic antioxidants to prevent lipid oxidation through free radicals scavenging, breaking chain reactions, peroxide decomposition, and decreasing oxygen concentrations and thereby increasing the shelf life [50]. But preservatives include sulfites, nitrates, benzoates, sorbates, formaldehyde, and others that may possess carcinogenic side effects. Thus nowadays the use of chemical preservatives in food industries steadily decreases and consumers are turning to the use of natural additives.

3.2 Natural additives

3.2.1 Plant-derived products

The use of plant-derived natural compounds such as essential oils, plant extracts, hydrocolloids, phenolic compounds, etc. is very popular in seafood preservation. Their strong antimicrobial and antioxidant activities present great potential for use in the food industry [64–66].

Plant extracts and essential oils can be derived from plant petals, leaves, fruits, peels, stems, roots, and xylems and their antioxidant effects are due to volatile organic compounds, terpenoid, and phenolic components in the plant. The inhibitory effects of essential oil on gram-negative bacteria are less than that of gram-positive bacteria as their lipopolysaccharide cell wall of gram-negative bacteria blocked the invasion of hydrophobic oils into the cell membrane [67]. Using essential oils (EOs) and plant extracts to extend shelf-life and maintain the quality of fish and fishery products has been reported frequently. Some of the recent studies of their application in fish and fishery products are represented in **Table 2**. However strong odor and taste, high volatility, complex chemical composition,

Plant derived compounds	Preservative properties	Product	Reference
Essential oils			
Rosemary	Retarded microbial growth, delay chemical deterioration, sensory qualities, and extend the shelf life for 14 days during storage.	Bonito Fish Patties	[68]
Rosemary and basil	Inhibited the formation of TVB-N and lipid oxidation products during storage	Atlantic Mackerel	[69]
Rosemary, laurel, thyme, and sage	Antimicrobial, antioxidant properties, and also enhanced the organoleptic quality	Rainbow trout fillet	[70]
Rosemary, cinnamon fennel and cardamom	The counts of *S. aureus, E. coli* and *Bacillus cereus* were reduced	Carp fingers	[71]
Green pepper	Inhibited the growth of wild type strain of *P. aeruginosa* and attenuated its virulence properties	Fish-based products	[72]
Orange leaf	Enriched with Gelatin film showed shelf-life extension of 10 days	Shrimps	[73]
Carvacrol, bergamot and grapefruit	Improved the quality of fresh fish and extended the shelf-life up to 4 days.	Seabream	[74]
Oregano, thyme, and star anise	Inhibited microbial growth and delaying lipid oxidation	Grass carp	[75]
Ginger	Significant reduction in the TVBN and lipid oxidation	Cobia steaks	[76]
Clove, cumin, and spearmint	Retarded sensory deterioration and formation of biogenic amines.	Red drum fillets	[77]
Black cumin	Higher sensory quality, and extended shelf life	Fresh fish fillets	[78]
limonene	Maintained spoilage bacteria at a lower level and extended the shelf-life of 15 days	Gilthead sea bream fillets	[79]
Allyl Isothiocyanate	Extended the shelf-life by maintain specific spoilage organisms at a lower level	Gilthead sea bream	[80]
Oregano	Activity against *Listeria* spp.	Salmon	[81]
Fennel	Coating with chitosan nanoparticles reduced the PV, TVBN, TBARS and microbial count	*Huso huso* fish fillets	[82]
Satureja thymbra leaves	Reduced peroxide value and eliminates secondary oxidation products	Gilthead seabream fillets	[83]
Lemon	Lowered accumulation of histamine, and improved sensory characteristics	Salted sardines	[84]
cinnamon bark	Inhibited *Aeromonas* and *Shewanella*, and reduced the accumulation of TVBN, putrescine, cadaverine	Grass carp	[85]
Plant extracts			
Cumin seed and Wild mint leaf	Retarded microbial growth, chemical deterioration, and improved sensory characteristics	Rainbow trout fillets	[86]
Shallot fruit and ajwain seed	Delayed lipid oxidation and microbiological spoilage	Semi-fried coated rainbow trout fillets	[87]

Plant derived compounds	Preservative properties	Product	Reference
Allium paradoxum and *Eryngium caucasicum trauve*.	Significantly delayed oxidative deterioration and maintain lower bacterial growth	Silver carp fillets	[88]
Punica granatum peels and *Hibiscus sabdariffa* calyxes	Colorant, preservative, and antimicrobial action	Burger and surimi	[89]
Nothopanax sutellarium leaf	Potential to preserve the fresh fish during transportation	Nile tilapia	[90]
Mint leaf and citrus peel	Retarded the quality changes and extended the shelf life	Indian mackerel	[91]
Syzygium australe and *S. luehmannii* fruit and leaf	Inhibition to *Shewanella* spp.	Fresh and cold storage fish	[92]
Kakadu plum	Inhibited bacterial growth for 15 days at 4°C	Fish fillets	[93]
Clove, Sage and kiwifruit peel	Antioxidant and antimicrobial potential, and extend the shelf life	Fish fingers	[94]
Pomegranate, rosemary, and olive	Delayed the lipid oxidation, and microbial count	Fish patties	[95]
Plectranthus amboinicus leaf	Improved the color, rehydration and water activity	Fish oil fortified soup powder	[96]
Green Tea Leaves and Fenugreek Seeds	Decreased TVBN, TBARS, total bacterial count, and pH	Shrimp	[97]
Basil leaf	Antimicrobial effect and longest shelf life	Mullet fillet	[98]

Table 2.
Summary of some of the recent studies of application of essential oils, and plant extracts in fish and fishery products.

low bioavailability and stability, and factors affecting chemical compositions like plant genetic variability, extraction techniques, etc. are some limitations for the application of these phytogenic additives [99]. Like other plant-derived products, seaweed and algal extracts are emerging as a rich source of natural antioxidants, along with many nutritional values. The three important widely used hydrocolloids are; agar-agar, align, and Carrageenan. As thickening agent agar-agar is used mainly in fish paste products. Carrageenan is used to enhance the gelling property of fish mince [100–102], and organoleptic properties of mussels and squids [103]. The sodium salt of alginic acid is widely used as a stabilizer and thickener in coating films. Sodium alginate coating with rosemary extract reduced the accumulation of biogenic amines and bacterial count in Abalone (*Haliotis discus hannai*) [104]. Coating with gingerol delayed lipid oxidation, protein degradation, nucleotide breakdown, and inhibited microbial growth in Seabream (*Pagrosomus major*) [105]. Coating with tea polyphenols had significantly lowered the levels of TVB-N, lipid oxidation, and protein decomposition in Japanese Sea Bass (*Lateolabrax japonicas*) fillets [106]. The use of alginate-calcium film coating with *Citrus wilsonii* extract delays the deterioration and results in a higher sensory score for *L. vannamei* [107]. Significant reduction in the TVB-N, TMA, and thiobarbituric acid reactive substance (TBARS) has been detected during chilled storage with the presence of *Gracilaria gracilis* extract in shrimp [108], *G. verrucosa* extract in Indian mackerel [109], and extracts of *Hypnea musciformis* and *A. muscoides* in black tiger shrimp [110]. Similarly, seaweeds like *Sargassum kjellmanianurn* [111], and *Grateloupia* *filicina* [112] exhibits a good antioxidant activity and prevent lipid oxidation in fish oil. Extracts of seaweeds such as *Fucus vesiculosus* inhibited the hemoglobin-mediated lipid oxidation in washed cod muscle and cod protein isolates [113], and extracts of *Durvillaea antarctica* (cochayuyo/ulte), *Pyropia columbina* (red luche), and *Ulva lactuca* (sea lettuce) improved the lipid and sensory qualities in canned salmon [114]. Some phenolic compounds like flavonoids, phenolic acids, hydroxy-cinnamic acid, and lignans are also used as plant derived natural additives [115]. In surimi-derived products, several hydrocolloids like konjac enhance the gelling property [116]. Other products like starch [101, 102], gums such as garrofin, guar, xanthan [117], etc. also provide a gelling effect and assure elasticity of the product. Iota carrageenan and xanthan had a cryoprotective effect too [118]. Other plant-derived products such as soybean protein, wheat gluten, and starch are also used as additives for fish-paste products [119].

3.2.2 Animal-derived products

Nowadays, animal-derived products like chitosan, gelatin, and whey proteins are widely used as food additives. Chitosan is a natural polymer obtained from chitin, a component of the exoskeleton of shellfish and fungal cell walls. Gelatin is a protein derived from the raw collagen of animal body parts. Whey protein is one of the two proteins, other than casein, found in milk. The bioactive coating of food products with these compounds provides antioxidant and antimicrobial properties and can thereby increase the shelf life of the product. Direct addition of compounds into the packaging materials also provided more potent preservative action [120]. Some of the recent studies on the application of chitosan, gelatin, and whey protein as edible coatings in fish and fish product preservation are represented in **Table 3**. But in moist environments, edible films and coating showed relatively low stiffness and strength, thus limited their use in specific conditions. Another animal-derived product, bioactive peptide (specific protein fragments) showed antimicrobial [137], and antioxidant activities [138]. In fish paste products, the products like plasma hydrolysate, plasma protein, ovomucoid, egg albumin, egg white, etc. were added as additives for improving strength [119]. The binding effect of egg whites and hydrolyzed beef plasma proteins in surimi gels [139], gel enhancing effect of bovine plasma powder, and egg white powder in arrow tooth surimi [140] were also reported.

3.2.3 Microbial-derived products

Bacteriocin, a major bacterial-derived bio preservative (mostly from *Lactobacillus*) has potent antimicrobial properties. The mode of action is interfering cell wall synthesis of bacteria by pore formation and squeezing out of the inner material thereby restricting their growth [141]. Along with this antimicrobial action, other properties like nontoxicity, active in a wide range of pH and temperature, etc. making them generally recognized as safe (GRAS) additive [142]. The most common bacteriocins produced by *Lactobacillus* are Nicin, lacticin, pediocin, etc. Many bacteriocins are known to be more effective against endospore-forming bacteria. Bacteriocins were used to reduce the counts of *Salmonella* and *Vibrio* spp. in marine fishes and loligo [143], *Listeria inaqua,* and *Pseudomonas* spp. in fish homogenates [144], and aerobic and anaerobic bacteria in cold smoked salmon [145]. A novel bacteriocin BCC7293 from *Weissella hellenica* showed activity against *L. monocytogenes, S. aureus, P. aeruginosa, A. hydrophila, E. coli,* and *S. Typhimurium* in Pangasius fillets [146]. Bacteriocin FGC-12 and DY4–2 produced by *Lactobacillus plantarum* showed some inhibitory effect on *Vibrio parahaemolyticus* in shrimp [147], and *Pseudomonas fluorescens* in turbot fillet

Fish product	Preservative action	Reference
Chitosan-based		
Grass carp	Inhibited cathepsin activities and thereby retarded the proteolysis	[121]
Olive flounder	Coating combined with clove oil improved the quality and shelf life was extended by 6 days	[122]
White shrimp	Coating combined with pomegranate peel extract reduced the melanosis, TVBN and microbial count	[123]
Mackerel	Coating combined with gallic acid decreased microbial growth, protein decomposition, biogenic amine formation, lipid oxidation and nucleotide breakdown and shelf life was extended	[124]
Fish burgers	The chitosan film containing lactoperoxidase system suppress the increase of *Pseudomonas* spp. and *Shewanella* spp. and TBARS value	[125]
Mori Fish	Spoilage reduction when coated with rosemary extract on storage	[126]
Gelatin-based		
Rainbow trout fillets	Coating incorporating oregano essential oil minimized the formation of volatile bases, oxidation products, and the growth of total and psychrotrophic bacteria	[127]
Shrimp	Fish gelatin reduced lipid oxidation and extend shelflife	[128]
Shrimp	Coating enriched with orange leaf essential oil extend shelf life about 10 days	[73]
Tilapia fillets	Combined with grape seed extract reduced the formation of undesirable metabolites like TMA and histidine significantly	[129]
Chitosan-gelatin-based		
Golden- pomfret fillets	Inhibits myofibril degradation	[130]
White shrimp	Decreased the total and psychrotrophic bacteria and increased the shelf-life	[131]
Salmon fillet	Incorporated with garlic and lime extracts extended the shelf life by antibacterial and antioxidant activity	[132]
Minced trout fillet	Incorporated with grape seed extract *Ziziphora clinopodioides* essential oil reduced the spoilage	[133]
Whey protein-based		
Pike-Perch	Coating with lactoperoxidase system and α-tocopherol extended the shelflife significantly	[134]
Rainbow trout fillet	Reduced microbial growth, and TVB-N and TBA	[135]
Rainbow trout fillet	Inhibited *Shewanella and P. fluorescens* and shelf life was extended	[136]

Table 3.
Some of the recent studies on the application of chitosan, gelatin, and whey protein as edible coatings in fish and fish product preservation.

[148] respectively. Bacteriocin LJR1produced by *Pediococcus pentosaceus* showed activity against *L. monocytogenes* in white shrimp [149]. Bacteriocin GP1 produced by *Lactobacillus rhamnosus* active against Coliforms, *Aeromonas*, and *Vibrio* spp. in fish fillets [150]. The combination of bacteriocins with other preservation techniques usually results in better action. Microencapsulated *Ziziphora clinopodioides* essential oil and Nisin showed the strongest effect on preserving the sensorial quality of fish

burgers [151]. However the use of bacteriocin is limited due to its high cost. Another microbial-derived product kojic acid, a natural product of many fungi like *Aspergillus* and *Penicillium*, has certain anti-enzymatic browning and antibacterial effects, especially against gram-negative bacteria [152]. A combination of kojic acid and tea polyphenols showed an antibacterial effect against spoilage bacteria in refrigerated seabass (*Lateolabrax japonicas*) [153]. ε-Polylysine is another microbial-derived product with excellent preservative properties. It was isolated originally from bacteria *Streptomyces albulus.* Treatment with ε-Polylysine lowered the TVB-N, putrescine, cadaverine, and hypoxanthine and extended the shelf-life of shrimp [154]. The addition of ε-polylysine chitosan and carrageenan showed shelf life extension of Chinese shrimp (*Fenneropenaeus chinensis*) [155], and chitosan-based coatings combined with ε-polylysine and rosmarinic acid contributed to the reduction of TVB-N, TMA, and ATP-related compounds in Half-smooth tongue sole fillets [156]. A combination of plant, animal, and microbial-derived products showed the strongest preservative action than the independent use.

Conclusions

As a perishable food commodity, most of the world's supply of fish and fishery products are lost through chemical and microbial spoilage than other reasons like improper storage, handling and processing damage. Thus, the increasing demand for good quality fish products has intensified the search for applications of additives in preservation strategies. It is well known that none of the additives offer complete protection against spoilage, but can improve the quality of fish as well as shelf life to a greater extent. By considering the potential health hazards associated with chemicals as well as consumer preference, application of natural products from cheap and underutilized resources enabling food safety holds promise.

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