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Study on the quality of fish products based on different preservation techniques: a review

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Abstract

This study aims to provide a summary of the most common procedures and how fish quality varies from harvest to plate. Fish is frequently seen as a challenging culinary product due to its proclivity for spoilage, oxidation, and the development of off-flavours as a result of improper treatment. Several variables have a major impact on the nutritional and sensory quality of fish preservation. In this study, the most widely utilized storing and preservation methods for fish will be discussed, as well as their influence on overall quality. It's critical to tailor processing to the unique needs of a product like fish, which is susceptible to bacterial deterioration and oxidation. However, items with excellent quality, good sensory characteristics, and a positive nutritional value may be obtained by combining and using preservation strategies in a creative way.

Keywords: fish; refrigeration; microbial spoilage; preservation techniques.

Practical Application: The quality of fish products based on different preservation techniques.

1 Introduction

Seafood and fish items, including aquatic plants, are nutritionally important, including healthy quantities of vitamins, vital minerals, lipids, and protein (Breda et al., 2017; Neiva et al., 2011). There is a strong relationship between eating fish and seafood and improving one's health and life expectancy. According to Tacon & Metian (2018), the country with the best average lifespan and the lowest rates of obesity and cardiovascular illness consumes considerably more aquatic fat and protein than the United States, where obesity and cardiovascular disease are big problems right now. Fish life regarded as foods is often low in calories, lean, and high in omega-3 (n-3) long-chain polyunsaturated fatty acids (LC-PUFA). Different health characteristics, such as neural and brain development, arteriosclerosis, diabetes, obesity, and metabolic syndrome, have been shown to benefit from n-3 PUFA (Denisenko et al., 2020; Liu et al., 2020; Zehr & Walker, 2018).

On the other hand, fish is frequently seen as a challenging culinary product due to its proclivity for spoilage, oxidation, and the development of off-flavors as a result of improper handling or storage. Several factors, such as the fish's diet, handling, and storage, substantially impact maintaining high nutritional quality in fish. In this study, the most widely utilized processing and storage methods for fish will be discussed, as well as their influence on overall quality. The goal is to provide an overview of the most common fish preservation techniques and procedures and the quality changes that occur as a result of them.

2 Techniques based on temperature

2.1 Cooling

Fresh fish is typically delivered and marketed on flaked ice, which keeps the temperature about 0 °C. Freshness can be maintained by refrigeration or cooling, but it will not kill or remove bacteria or stop the enzymatic activity. Most biological deterioration processes are slowed down (Yu et al., 2019). Melgosa et al. (2021) demonstrated that, for example, hydrolysis was three times quicker at 20 °C than at 0 °C in cod. Furthermore, at lower temperatures, microbial development slows.

On the other hand, psychotropic bacteria flourish around 0°C and may degrade food quickly, even at cold temperatures. The rate of growth of *Shewanella putrefaciens* at 0 °C is less than one-tenth of that at the optimal growth temperature (Wright et al., 2016). Colder water fish and shellfish, for example, can contain *Sh. putrefaciens* and thus deteriorate faster than fish from warmer waters (Gram & Melchiorsen, 1996). As a result, cold-water shrimp deteriorated more quickly than warm-water shrimp (Shakila et al., 2006).

After the fish has been killed, begin cooling as quickly as possible. For example, Jeyasanta et al. (2013) found that postponing icing for 4, 6, 8, or 10 hours reduced the storage life of Malabar trevally to 14, 10, 6, and 3 days, correspondingly, compared to an 18-day shelf life when the icing was done immediately. The

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shelf life of rainbow trout (*Oncorhynchus mykiss*) was reduced from 9–11 to 5–7 and 1–3 days, respectively, by delaying icing by 4 or 8 hours after capture. To ensure the desired shelf life, adequate refrigeration must be maintained during the whole shipping and storage duration (Alice et al., 2020). On-board fishing vessels, in addition to conventional ice flakes, chilled seawater (made by adding ice to saltwater) and mechanically refrigerated seawater (RSW) have become popular. These devices have been demonstrated to keep fish and shrimp from spoiling faster than regular ice. This was thought to be related to the usage of chilled water, which created greater anaerobic conditions. However, if partial deterioration occurs, the rotting organisms will be spread throughout the load, which is a significant disadvantage of this liquid cooling method. RSW that has had CO_2 injected into it has shown to be much more effective. Nevertheless, the CO2-modified RSW induced sensory alterations in the fish during frozen storage by increasing salt absorption and increasing rancidity (Ashie et al., 1996). Ice slurries, also known as flow ice, have been utilized more lately (Andrzejewski et al., 2010; Guzmán et al., 2021; Keys et al., 2018). Because of their greater heat exchange capacity, these water–ice systems may achieve temperatures below zero faster, protecting the fish from oxidation and dehydration. Furthermore, ice slurries have more spherical particles than flakes, resulting in less physical damage (Pamitran et al., 2013; Piñeiro et al., 2004). Different additions to the fish as well as the ice slurry have been utilized to improve the effectiveness of these ice slurries. Natural antioxidants, ozone, and organic acid combinations are examples of these substances.

The speed with which food is chilled has a significant impact on the quality of the finished product, not only in terms of oxidation and spoilage but also in terms of texture. The red muscle of fish may contract up to 52% during rigor mortis, whereas the white muscle can contract up to 15%. A condition known as cold shorting can occur when a temperature near zero or below ten °C is reached before the fish has attained rigor mortis. This will culminate in a more difficult texture and an increased chance of gaping. Because the enzyme system is no longer functional, the fish muscle tightens and cannot extend again. Due to the poor activity of calcium-related enzymes at these low temperatures, calcium ions release rapidly (Duarte et al., 2020).

2.2 *Freezing*

Freezing has long been thought to be an adequate strategy for preserving meat for extended periods of time (George, 1993); nevertheless, freezing can severely impact chemical and structural characteristics of muscle, such as increasing the concentration of free fatty acids (FFA) and lipid oxidation products (Zhan et al., 2018). Freezing reduces enzymatic and microbial activity, preserving taste and nutritional qualities more effectively than cold storage (Yu et al., 2020). The production of ice crystals while freezing, on the other hand, is a key moment, and the larger the ice crystals generated, the greater the danger of membrane rupture and textural damage, leading to enhanced oxidation (Sikorski & Kolakowska, 2020). During freezing, the production of tiny ice crystals should be considered essential in avoiding enhanced oxidation and textural degradation following thawing. The produced ice crystals will be smaller and more consistent if the freezing process is faster and more homogenous (Sigurgisladottir et al., 2000) (Figure 1).

According to Dalvi-Isfahan et al. (2019), the cells should be pliable enough to avoid being harmed by larger ice crystals.

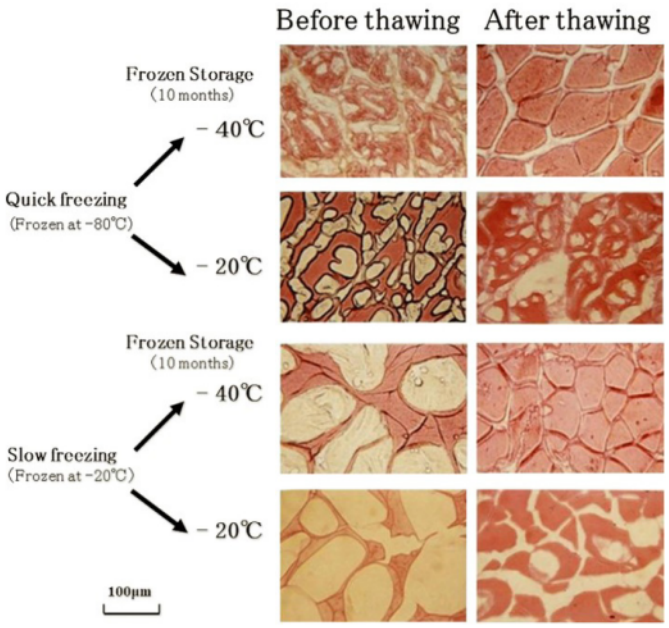

Figure 1. Chub mackerel muscle fibre tissue is affected by freezing rate and freezing storage temperature.

Regardless, You et al. (2021) demonstrated that slower freezing led to larger ice crystals and severe muscle fibre injury. Yet, it's been pointed out that cryogenic freezing can cause intracellular ice crystallization in cells, which can lead to mechanical breaking. Although the breakdown of the cells does not increase fluid loss, it may enable oxygen passage to the cells and tissue, therefore increasing oxidation (Zhu et al., 2019) (Figure 2).

Pressure shift freezing or high-pressure freezing, liquid immersion freezing, cryogenic freezing, and the longer utilized air blast freezers and plate freezers are among the most recently discovered rapid freezing procedures for muscle foods. Plate freezers are ideal for common fish and goods because they guarantee optimum contact between the food and the surface. They work best at around -40 °C. For items of diverse forms, air blast freezers are the most effective and economical technique. The items are either put in a room or transported through a tunnel with a variable-speed cold airflow (Fidalgo et al., 2021; Hall, 2011). The flow of air can be provided horizontally and/or vertically when the goods are moving on a belt. The speed at which the product freezes will be determined by a mixture of belt speed, product load, and airflow parameters. Temperatures somewhere around -20 and 40°C are typical for air blast freezers. In immersion freezing, the packaged items are dipped or sprayed with a liquid freezing media such as brine, propylene glycol, or ethylene glycol (Gökoğlu & Yerlikaya, 2015). This freezing technology can function at greater temperatures than plate and air blast freezers at temperatures between -6 and -20 °C with the same speed but higher efficiency, thanks to direct contact with the whole product surface. The same process as immersion freezing is employed in cryogenic freezing, except the liquids are liquid nitrogen or carbon dioxide instead of water (Tavares et al., 2021).

The fact that water freezes at a lower temperature under higher pressure are exploited in high pressure or pressure-shift freezing. The products are heated to a temperature just over the melting temperature of ice at this pressure before being cooled under pressure. The pressure is then quickly released, resulting in supercooling and the production of ice crystal nucleotides in the cooled sample in an instantaneous and homogenous manner (Cziko et al., 2006). In a typical freezer, the final freezing takes place at air pressure. This method is very effective for freezing huge quantities of food. Nevertheless, until recently, the interior diameter of a large-scale high-pressure vessel has been restricted. It seldom exceeds 30 centimeters in most situations (Alizadeh et al., 2007).

Aside from alternative freezing procedures, injecting or dipping antifreeze proteins into meat or fish has shown some efficacy in forcing the production of tiny ice crystals (Mathew et al., 2019; Ustun & Turhan, 2020). Antifreeze proteins have also been found to prevent tiny ice crystals from recrystallizing into larger ice crystals (Eskandari et al., 2020).

3 High-Pressure Treatment (HPT)

The notion that high pressure may kill germs was established in 1899, but research on food preservation began in the late 1980s and early 1990s. In 1990, the Japanese market saw the introduction of the first pressure-preserved foods. High pressure has the same effect on bacteria and enzymes (Rastogi et al., 2007). On the other hand, high pressure might result in cell damage and deformation, resulting in structural alterations and damage. Changes in pressure up to a range of 100–300 MPa are stated to be likely reversible in most food products, in contrast to changes caused by temperature. However, for example, bacterial spores may withstand high pressures and may require up to 1,200 MPa to be inactivated (Abera, 2019) (Table 1).

High pressure can denature proteins depending on their structure and kind. Rastogi et al. (2007) go over the many types of denaturation and how they are done. As a result, because high

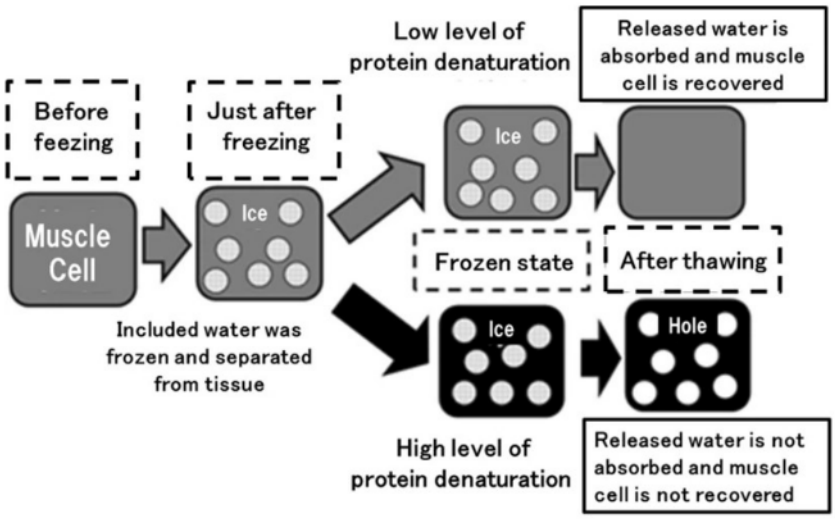

Figure 2. In the freezing and thawing of fish muscle tissue, the behavior of water and proteins is studied.

Table 1. HPT inactivates foodborne microorganisms.

Product	Pressure	Time	Target	Microbial Reduction
Mackerel (Scomber scombrus)	300 MPa	5 mins	Mesophilic bacteria	1.7 log CFU/g
Haddock (Melanogrammus aeglefinus)				> 1.0 log CFU/g
Mackerel (Scomber scombrus)	250-400 MPa	0-60 mins	Escherichia coli (O157:H7)	2-4 log CFU/ml
			Listeria monocytogenes (Scott A)	1-3.5 log CFU/ml
Albacore Tuna (Thunnus alalunga) minced	275-310 MPa	2-6 mins	Mesophilic microorganism	< 2 log CFU/ml
Black Tiger Shrimp (Penaeus monodon)	100-435 MPa	5 mins	Total Microorganism	0.1-1.2 log CFU/g
			Escherichia coli	0.4-1.5 log CFU/g
			Staphylococcus aureus	0.3-1.0 log CFU/g
Pacific oysters (Crassostrea gigas)	207-310 MPa	0-2 mins	Coliform	2-3 log CFU/g
Oysters	200-300 MPa	5-10 mins	Vibrio parahaemolyticus	> 7.4 log CFU/g
Oysters (Crassostrea virginica)	150-300 MPa	1-20 mins	Vibrio vulnificus	3.0 log CFU/ml
Atlantic salmon (Salmo salar)	0-300 MPa	15 mins	Total Aerobic	2.0-3.0 log CFU/g
Octopus (Octopus vulgaris)	150-600 MPa	6 mins	Psychrotropic bacteria	0.1-2.8 log CFU/ml
Mussels (Mytilus edulis)	300-600 MPa	2 mins	Total Aerobic	1.0 log CFU/g
			Pseudomonads	3.0 log CFU/g
			Coliform	2.0 log CFU/g
Dublin bay prawns (Nephrops norvegicus)	300-600 MPa	2 mins	Total Aerobic	1.0 log CFU/g
			Pseudomonads	3.0 log CFU/g
			Coliform	2.0 log CFU/g
Scallops (Pecten Maximus)	300-600 MPa	2 mins	Total Aerobic	1.0-1.5 log CFU/g
			Pseudomonads	1.0-2.0 log CFU/g
			Coliform	< 1.0 log CFU/g
Oysters (Crassostroea gigas)	300-600 MPa	2 mins	Total Aerobic	1.0 log CFU/g
			Pseudomonads	2.0 log CFU/g
			Coliform	-
Squid (Todarodes pacificus)	200-400 MPa	1-2 mins	Psychrotrophic bacteria	0.5-6.0 log CFU/g
Chilled cold-smoked salmon	0.1-250 MPa	20 mins	Listeria monocytogenes	< 0.5 log CFU/g

pressure can influence proteolysis, myofibrillar proteins, and muscle enzymes, the impacts on sensation and texture must also be considered. Color changes and tenderization in meat have been linked to high pressure (Figure 3).

For fish, both are undesirable. Ekonomou et al. (2020), on the other hand, demonstrated that inactivating Listeria monocytogenes in smoked salmon required a high-pressure treatment of 200 MPa and freezing to -18 °C. They emphasize the bacteria's inactivation by combining pressure holding duration and pressure with sub-zero temperatures. The authors also noticed a change in hue and hardness, but they decided that this would be acceptable to customers. Matějková et al. (2013) discovered that vacuum-packed trout subjected to high-pressure treatment and kept at 3.5 °C had low levels of biogenic amines. They have the potential to increase the shelf life from 5–6 days to 21–28 days. Samples exhibited good organoleptic characteristics, according to the author. On the other hand, Unni et al. (2011) came to the conclusion that the high-pressure processing of marine foods had a lot of promise. They examined the effect of 300 MPa at 20 °C for 5, 10, and 20 minutes and discovered lower microbial counts and trimethylamine levels, as well as higher activity of proteolytic enzymes, which resulted in more myofibrillar protein breakdown. The researchers, nevertheless, did not specify how this impacted the squid's final texture. Unlike entire fillets, gelatinized fish products such as surimi appear to benefit from the pressure treatment.

4 Modified atmosphere and vacuum packaging

During the previous few decades, packaging techniques and applications have advanced quickly. Food, particularly meat, is being stored in modified atmospheres in increasing numbers. Using this approach, a product can be stored in a specified gas mixture (Özogul et al., 2004). Ordinary aerobic bacteria like *Acinetobacter* and *Pseudomonas* are inhibited by increasing the CO_2 concentration. CO_2 also possesses fungistatic characteristics in addition to bacteriostatic ones. Oxygen, nitrogen, and carbon monoxide are the most often utilized gases (Cachaldora et al., 2013). In order to maintain a brilliant red hue, which is a symbol of freshness for customers, a relatively high amount of oxygen is retained in the package for meat. Furthermore, *Clostridium botulinum* type E needs oxygen to develop. Nitrogen is commonly utilized as a filter gas to keep packaging stable and avoid collapse (Arashisar et al., 2004).

Unsaturated fat is greater in fish than in animals, which increases the danger of quick oxidation of various gas combinations (Rustan & Drevon, 2005). Gas mixtures with no oxygen are typically advised for fatty fish due to the increased risk of oxidation. As a result, there have been worries about *C. botulinum* spreading in

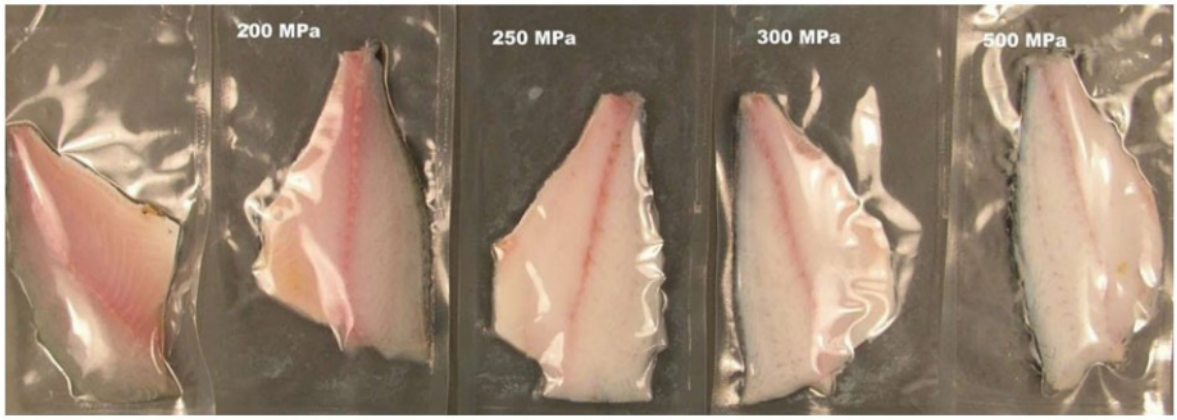

Figure 3. The high-pressure treatment causes colour changes in sea bream (*Sparus aurata L.*) fillets.

seafood items that have been kept with little or no oxygen (Mason & Sherratt, 2017). Sivertsvik et al. (2002) discovered that fatty fish had a narrower safety margin between spoiling and toxin generation than lean fish. Hyytiä et al. (1999) created a model to estimate the lag time of *C. botulinum* before toxigenesis and discovered that storage temperature accounted for 75% of the variance, while spore type, type of fish, and gas composition accounted for the remaining 2.3 percent. However, using solely CO_2 is challenging since it is extremely soluble in fish muscle and, as a result, can cause the package to collapse. As a result, nitrogen is supplied since it has low solubility in both water and muscle, allowing it to maintain the package.

Cod has been the subject of extensive study into various gas combinations and storage temperatures, with storage times ranging from 2 days at 26 °C in the air to 55–60 days at 4 °C with 75 percent CO_2 and 25 percent N_2 (Debevere & Boskou, 1996; Sivertsvik, 2007). At temperatures ranging from 0 to 4 °C, a changing environment would double or triple storage duration, depending on the gas combination, but vacuum-packed cod had an intermediate shelf life (Hansen et al., 2016). Ouk et al. (2011) used a combination of vacuum packing and super chilling to extend the shelf life of iced samples in vacuum-packed samples held at -1.4 or 3.6 °C from 17 to 21 days. When compared to the quality at day 0, the extremely cold samples had a firmer texture, while the ice-stored samples had a softer texture. Salmon was also shown to be more suitable for super chilling than cod, according to these researchers. Regrettably, oxidation in normal vs. vacuum packing has not been studied in these investigations.

Furthermore, studies are being conducted to better preserve fish from oxidation in modified atmospheric packaging (MAP) (Das et al., 2021; Hauzoukim & Mohanty, 2020).

5 Irradiation

Because of the antibacterial properties of ionizing radiations, food irradiation extends the shelf life of the items. Irradiation damages microbial DNA, interfering with their regular metabolic activities in the process (Sanzharova et al., 2021). Small concentrations of irradiation of 1.5–2.5 kGy were shown to be extremely efficient in killing bacteria such as *Escherichia coli, Salmonella, Pseudomonas,* and even prevented the formation of toxin from *C. botulinum* spores. On the other hand, Irradiation is known to produce hydroxyl radicals, which might result in enhanced oxidation in seafood products (Brazhnaya et al., 2019).

Microorganisms were totally eradicated in seafood at high dosages of 50 kGy, although the texture and taste were altered. Furthermore, the WHO established a 10 kGy upper limit for food processing. As a result, due to quality changes, such processing is not permitted or even desirable (Nickerson et al., 2018).

6 Conclusions

Every stage in the process, as well as added components, will have an impact on the quality of the aquatic products. It's critical to tailor the preservation method to the unique needs of a product like fish, which is susceptible to bacterial deterioration and oxidation. The preservation of general quality, sensory and textural qualities, as well as the nutritional value of fish products, can be achieved by using an optimal chilling or freezing technique in conjunction with antioxidant compounds, irradiation, or modified atmosphere packaging. To achieve the optimum effects, the cooling or freezing regimen should be meticulously planned and carried out. Because they can lower microbial counts, high-pressure treatments offer a lot of promise for marine items. On the other hand, high pressure may affect several functional and sensory features of fish, necessitating a thorough examination of processing factors for diverse species.

High pressure appears to be most beneficial in gelatinized goods like surimi, leading to a better texture. Gas mixtures with low oxygen levels must be selected when utilizing a modified atmosphere. To prevent spoiling caused by the anaerobic bacterium *C. botulinum*, a secondary preservation method such as chilling to 0 °C must be selected. Irradiation also has a lot of promise since it can efficiently destroy a lot of germs. High dosages, on the other hand, have been found to lower

sensory characteristics and promote oxidation. Furthermore, the current analysis demonstrates that combining and using the provided storage and preservation strategies in a creative and well-planned manner will result in high-quality goods with positive nutritional content.

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