Quality assessment of fish products: An introductory mini-review

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Abstract. The concept of quality of fish products is a subjective or objective concept according to different forms of interpretation. However, there are some internationally agreed fish quality and safety standards based on scientific knowledge and research. This paper aims to systematically review the studies on the characteristics of quality concept of fish products, specifically focusing on sensory and instrumental methods for quality evaluation. In order to provide a good overview of the quality of the fish product and especially of the state of freshness, sensory and instrumental methods must be corroborated, because of their advantage. However, when singularly used, they also have many disadvantages.
Key Words: instrumental evaluation, freshness, sensory evaluation, spoilage.

Introduction. As a result of fish farming activities, there is a great diversity of fish species and fish food products that are available to consumers as quality food (Tidwell & Allan 2001). Fish products are available in many different forms, live, fresh or frozen, consumed raw or thermally processed according to different culinary recipes, at home, in restaurants or industrially processed in specialized units (Moody 2003). Due to an increasing demand in fish meat products, there are major developments in production, handling, processing and distribution of fish. Along with these, food quality and safety have been made a priority both for consumers and producers, and even for researchers (Valdimarsson et al 2004; Ababouch 2006). Food products from the aquatic environment are highly perishable and prone to contamination at all stages of the production chain such as fishing, storage, processing and distribution, resulting in undesirable effects on the health of final consumers.

Appreciated as functional foods, with a high nutritional value and tasty qualities, fish and fish products have come to the attention of consumers as being also very sensitive products prone to perishability (Qiu et al 2022), placing a great emphasis on food safety and quality. The aim of this paper is to systematically review the studies on the characteristics of quality concept of fish products, specifically focusing on sensory and instrumental methods for quality evaluation.

Quality and Safety Concepts of Fish Products. Food quality and safety are two of the most important aspects of any food product. Although they differ in principles and definitions, they form a proper food management system and usually go together in the direction of consumer satisfaction (Van Rijswijk & Frewer 2008). Food quality includes several characteristics that make food acceptable to consumers. Quality characteristics include external factors such as appearance (size, shape, color, gloss, texture, flavor), factors such as certain predefined compliance standards, and internal factors such as food safety through a main attribute like the presence of a food safety hazard (Sadilek 2019).

According to Lefevre & Bugeon (2008), there are several perspectives on food quality, requiring different characteristics. Thus, biological quality is related to species and age, technological quality to the growth system and primary and final processing, nutritional quality to micro and macro nutrients, and organoleptic qualities include the sensory perception of products including texture, appearance, aroma and color.

Food safety refers to the processing, handling and storage of food products avoiding contamination with compounds toxic to the human body. Food safety concerns for fish products can be biological (due to bacteria, viruses or parasites) and chemical (biotoxins), due to environmental sources of growth or anthropogenic sources (Dos Santos & Howgate 2011). Hazardous chemicals for example, persistent and toxic bioaccumulative compounds such as dioxins, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenics (PCBs) and heavy metals (mercury, lead or cadmium) can bioaccumulate in fish along the food chain or during their processing (Vergis et al 2021).

Most food safety hazards associated with aquaculture products can be controlled by integrating good farm management practices with existing regulations that include recognized food safety guidelines or systems (Erondu & Anyanwu 2006), such as hazard analysis and critical control points (HACCP), management total quality (Total Quality Management - TQM) or quality assurance programs (Quality assurance - QA) at the processor or manufacturer. In addition, aquaculture facilities must operate in such a way as to comply with the provisions and recommendations of the Codex Alimentarius Code of Practice for Fish and Fishery Products (Codex Standard CXC 52-2003) to minimize the likelihood of potential food safety hazards during production, harvesting and processing. The provisions and recommendations and refer to: risks for fishery products, disease prevention and control, selection of production, processing, storage location, water quality, use of feeds and treatments, growth technologies, harvesting procedures, processing methods, materials and equipment used in processing (Hicks 2016).

While food safety is clearly the most important parameter of quality, sensory characteristics such as smell, aroma, shape and texture are the major attributes that consumers can easily judge in accepting or rejecting the food product (Lougovois & Kyrana 2005). Fish quality is a very complex representation of attributes affected by numerous factors, and in general terms quality cannot be seen as a specific object that can be directly measured, but is a complex concept that involves different thoughts in different people depending by socio-economic status, education and lifestyle, age, etc. (Olafsdottir et al 1997).

Quality is frequently described using terms related only to nutritional, microbiological, biochemical and physico-chemical characteristics (Nielsen et al 2002). However, for consumers, "quality" mostly refers to the aesthetic appearance and freshness or degree of alteration of the fish. Looking at other aspects of quality, fish acquire a certain specificity both in terms of the nutritional quality of the meat due to their composition, and in terms of their sensory quality due to the particular structure of the muscle components (Lefevre & Bugeon 2008). Freshness is defined by specific sensory attributes of fish (look, smell, flavor and/or texture) and is assessed consciously or unconsciously each time a product is consumed and is therefore an extremely important factor in determining the general quality of fish. To preserve freshness and original quality characteristics, a certain control is needed over all post-fishing stages, as well as post-mortem storage and processing conditions.

Nimbkar et al (2021) describe very specifically the biochemical processes that occur in post-mortem fish that have direct implications for sensory, food safety and quality attributes. Thus, after the death of fish, blood circulation ceases resulting in the unavailability of oxygen. With the depletion of glycogen, adenosine triphosphate (ATP) is no longer available, resulting in the state of rigor mortis. Proteolytic enzymes such as cathepsins, calpains, alkaline proteases and collagenases are attributed to the rigor mortis state, having great implications mainly on textural properties. ATP in fish muscle is degraded into adenosine diphosphate (ADP), adenosine monophosphate (AMP), ionosine monophosphate (IMP), ionosine, hypoxanthine, xanthine and, finally, into uric acid through several biochemical reactions.

Quality Assessment of Fish Products. Quality assessment is part of quality assurance that focuses on meeting quality requirements (Mainz et al 1992), being necessary to protect consumers against any risk associated with the consumption of fresh and processed fish products. York & Sereda 1994 state that the development of quality assessment methods was encouraged by two aspects. The first aspect was the need for improved

standards for the testing and certification of fish products, and, to this end, there have been developments in standards both nationally and internationally through the Codex Alimentarius. The second aspect was the accentuation of quality degradation due to the appearance of environmental pollutants, as well as the increase and diversification of toxic compounds due to storage and processing technologies. Freshness verification methods are needed in the fish industry at various points in the transaction from catch to consumer, at all levels of trade, from wholesale to retail (Zhang et al 2022). The internal evaluation of raw materials is carried out regularly in the fish processing units, in quality control for the use of the raw material received and during the processing of the products for compliance with the given specifications. Detection of bruises, bones, scales, parasites, blood stains, etc. is part of the inspection carried out through sensory evaluation and is mostly conducted by specialized employees (Martinsdóttir 2010).

The chemical composition influences directly nutritional and sensory qualities of the fish product and can vary, even within the same species. According to this, several studies have been carried out that aimed to determine the factors and changes that take place in fish quality (Fallah et al 2011; Nisa & Asadullah 2011; Ali et al 2013; Abraha et al 2018). Variations in the physico-chemical composition of fish are largely due to the following three aspects with direct effect on the general quality: species; rearing technology, season and environment; and processing and preservation methods.

The species. It was found that the biological factors related to the species contribute significantly to the chemical composition of the fish meat. In the case of proteins, big differences have not been observed in terms of the amount and content of essential amino acids. However, for fats and micronutrients, significant differences have been observed, varying greatly (Ahmed et al 2022). According to Banu et al (2010), these chemical content variations are due to the environment in which they growth (freshwater, marine, oceanic, stagnant or flowing water), migration status (migratory or non-migratory) and feeding method (predators, herbivorous, omnivorous or planktonophages).

Rearing technology, rearing season and rearing environment. These factors can have effects on the chemical composition of fish, with changes observed in both wild and farmed fish. The chemical composition of farmed fish is directly influenced by factors such as rearing system, rearing intensity and feed administered. Feed has the most pronounced impact because the growth potential is optimized when the fish is fed with a high lipid content for energy purposes and a large amount of protein with a well-balanced amino acid composition. Huss (1995) describes the differences in composition due to the applied rearing technology and highlights the fact that the fish farmers are able to design the composition of the fish, according to market requirements, selecting the optimal rearing conditions for the intended purpose. The author also notes that, within certain limits, predetermining the composition of fish in farmed systems and keeping the fish in captivity under controlled conditions also provide the opportunity to conduct experiments and to analyze the induced variation in chemical composition observed, sometimes being possible to draw conclusions even for wild fish.

Processing and preservation methods. These are represented by various low or high temperature treatments, including cooling, freezing, drying, salting, smoking, roasting, fermentation, or combinations of these, with the aim of giving the product a shape, color and taste attractive to the consumer and to extend the shelf life (Sitaram 2021). These methods and techniques have significant effects on the physical, chemical and nutritional composition of fish due to the fact that heating, freezing and exposure to various substances lead to physical and chemical changes. Processing methods primarily affect the basic components of the meat, namely water content, protein, fat, vitamins and minerals, as well as sensory attributes such as aroma, texture, color or smell. These changes are based on biochemical processes such as denaturation, coagulation or oxidation. The extent of these changes depends on the type of treatment applied, with all these changes affecting the final quality of the fish and fish products (Abraha et al 2018).

Methods of Evaluation. The methods for evaluating the quality of fish products can be divided into two categories (Huss 1995): sensory methods and instrumental methods, with several methods available and developed for measuring the quality of fish. Quality evaluation is mainly based on sensory methods, but in the last decades, through scientific developments in instrumental techniques, new methods have been created for measuring fish products. Statistical methods for analyzing and interpreting data have also been employed.

Sensory evaluation of fish products. The sensory evaluation is one of the most important methods of freshness and quality assessment, as a fast and accurate tool that provides relevant information about the fish product. Mohan et al (2018) define sensory evaluation as a scientific discipline that is based on analyzing one or more of the five senses (sight, smell, taste, touch, hearing) and follows certain known attributes of the product (general appearance, size, shape, gloss, smell, taste, texture, fluidity, fragility). Thus, sensory evaluation is actually the quantification and interpretation of variations in the characteristics of the food product (Torry Advisory Note No. 91, 1989).

The evolution of sensory science in the context of food science has demonstrated that the sensory evaluation can be both subjective and objective, depending on the evaluator, the purpose pursued and the testing methods applied. In the case of objective sensory evaluation, trained evaluators use recognized methods to classify freshness, while in subjective perception, interpretations based on consumer satisfaction and analysis of fish markets are utilized (Tahsin et al 2017).

For the sensory evaluation of the freshness of fish, three methods are predominantly used by both producers and traders active in the fish industry: the European E-A-B scheme, the Torry scheme, and the Quality Index Method (QIM).

The European E-A-B scheme. This is widely used in European countries. In this analysis method, four degrees of freshness are established, corresponding to different stages of freshness: (E-EXTRA) is the highest quality possible; (A) represents good quality; (B) represents satisfactory quality; and (N) is the level where the fish is considered unfit for human consumption. The European E-A-B scheme applies to marine fish classified under CN code 0302, crustaceans classified under CN code 0306, cephalopods classified under CN code 0307, scallops and other aquatic invertebrates within the scope of CN code 0307. Whitefish, whole and eviscerated, are evaluated regarding the appearance of the tegument, integumentary mucus, eyes, gills, peritoneum, blood vessels, the smell of the gills and the abdominal cavity, and the texture of the meat (Regulation 2406/1996).

The Torry system. This is a systemic method of scoring fish freshness, originating in Great Britain, widely used both in food chains for cooked fish and in research laboratories in Europe for whole fish or fillets (Martinsdottir 2010). The scoring system is represented by a descriptive scale that starts with a score of 10 for a very fresh state and goes down to a score of 3 that represents a high degree of deterioration, unfit for human consumption. A score of 6 is considered the consumption limit, and below this value consumers usually reject the product because obvious spoilage characteristics such as sour smell and uneven appearance are detected. Generally, the Torry scoring system only refers to a few species of fish such as cod, herring, mackerel, hake, salmon or trout, and there is the possibility of creating a scoring system for species that are not referred. Analyzing the systems presented by Archer (2010) for different species, the scheme for the cod species can be considered sufficiently complex to be used for other species as well.

The Quality Index Method. This is a tool for sensory assessment originating from Tasmania, but developed in Europe (Nielsen 2005). It considers relevant characteristics of each species, and it can also predict the shelf-life of a fish or crustacean product (Huidobro et al 2001; Esteves & Anibal 2007). However, the method does not determine quality aspects, but establishing degradation rates of established criteria (Green 2011; Bernardi et al 2013).

The instrumental evaluation of fish products. Instrumental evaluation involves the use of non-sensory methods that require laboratory equipment and specialized evaluators that analyze the main physical, chemical and biological changes in the initial state of the fish (Wardencki et al 2009). It has several notable advantages compared to sensory evaluation, like high objectivity and reliability, as well as low variability. It is considered to be a disadvantage that the instrumental evaluation usually measures only one aspect of the alteration. Previous to the instrumental evaluation, it is recommended to apply a sensory evaluation method, which is practically a decisive factor in the process of accepting or rejecting the fish food product (Hassoun & Karoui 2017). In the case of sensory evaluation, the utility is given by the identification of very good or very poor quality products, while the instrumental evaluation conducts a sensitive analysis of products of marginal quality.

Although it is a difficult goal to achieve, the instrumental methods must be as accessible and less invasive as possible, correlating factors such as the fish species, the storage period and the state of freshness, resulting in an estimation of the degree of deterioration at the end of the assessment and of the subsequent conservation period (O'Sullivan & Kerry 2013). The inclination towards the instrumental methods of assessing the quality of fish products is related to the possibility of establishing objective quantitative standards that can be further used, including in litigation situations before a court.

Some instrumental quality assessment methods are based on physico-chemical or microbiological tests, while others will rely on biological changes to indicate degrees or characteristics of the stages of deterioration. In addition to these mentioned methods, there are more recent techniques for assessing quality and freshness that represent an alternative to traditional analysis with several benefits. These technologies are listed by Duarte et al (2020) and include enzymatic biosensors, electrochemical biosensors, "electronic nose and tongue", colorimetric sensors, computer vision techniques, near-infrared spectroscopy (Vis/NIR), hyperspectral imaging (HSI) spectroscopy, mid-infrared fluorescence spectroscopy (MIR) and nuclear magnetic resonance (NMR).

A variety of chemical compounds or groups of compounds accumulate in fish muscles post-mortem (Alam 2007). After slaughtering the fish, anaerobic conditions result in the muscles, developing certain biochemical changes that significantly affect many of its properties as a food. These chemicals are either intermediate or end products of the biochemical changes that occur in the muscles of fish after death (Hultin 1984). In addition, the major chemical components in fish meat such as water, lipids and proteins greatly influence its quality, which is why it is useful to analyze samples from the time or day of harvesting to different periods or storage conditions. The chemical composition can vary depending on the species, sex, season, place of harvest, feeding status, and others. Thus, it is often impossible to apply a standardized analysis for all fishery products.

Chemical and biochemical analysis is based on the analysis of compounds resulting from the decomposition of fish and fish products. These compounds usually include:

a) Volatile amines: dimethylamine (DMA), trimethylamine (TMA), ammonia, total volatile basic nitrogen (ABVT);

b) Biogenic amines: histamine, putrescein, agmatine, cadaverine, tyramine, tryptamine, 2-phenylethylamine, spermine, spermidine;

c) Nucleotide catabolites: adenosine triphosphate (ATP), adenosine diphosphate (ADP), adenosine monophosphate (AMP), inosine monophosphate (IMP), inosine (Ino), hypoxanthine (Hx), xanthine (Xa), uric acid;

d) Ethanol;

e) Peroxide index (PV);

f) Thiobarbituric acid reactive substances (TBARS).

After slaughtering fish, the effects of variations in physical properties on quality are obvious and direct (Cheng et al 2015). These physical properties allow the determination of parameters of fish quality degradation, such as: evaluation of texture, color, shape and size, pH determination, determination of electrical conductivity (EC).

Color changes resulting from autolytic and microbial activity in the decay process of fish may include the development of a yellowish color in the flesh or brown discoloration (Duarte et al 2020). The texture of fish depends on its fat and collagen content and it is a very important characteristic. The texture can be dry and hard in frozen products after thawing, revealing problems in the freezing and maintaining temperature processes (Borderias et al 1983). Changes in color, texture, and shape of fish can be assessed with bright light and electron microscopy, as well as with measuring devices called texture analyzers. However, the texture and shape of whole fish muscle is difficult to measure, because it lacks a uniform structure, thus making it difficult to prepare samples with standard content. This leads to a variety of sample preparation procedures and variable results and applications for different methods (Olafsdottir et al 1997).

Some of the physical changes in fish meat can be measured electrically (Oehlenschläger 2003). These methods rely on equipment that can be expensive, but usually provide a very quick result. After slaughtering the fish, certain autolytic processes take place in its meat through enzymatic action that progressively destroy the cell membranes, so the intracellular fluid reaches the cell space, which is an electrolyte with electrical conductivity. Consequently, there is a decrease in both the electrical resistance R and the capacity C of the tissue. The operating principle of the portable instruments is based on the one hand on the measurement of the conductivity of the sample, conductivity that increases with the alteration process, and on the other hand on the measurement of the electrical resistance that decreases following the previously described process (Niu & Lee 2000). There may be problems with the interpretation of the results, especially if the fish was frozen before testing.

The activity of microorganisms is one of the main factors that cause the spoilage of fish, especially due to biological contamination with pathogenic bacteria, viruses, parasites and biotoxins, whose appearance is mainly due to some improper handling practices or insufficient heat treatments (Gram & Dalgaard 2002). The accumulation of microorganisms is due to intrinsic factors such as pH, oxidation-reduction potential and antimicrobial constituents, or extrinsic factors belonging to environmental limitations such as temperature, relative humidity, atmosphere and external microbial activity (Duarte et al 2020).

The total viable count (TVC) is a traditional indicator used to evaluate the freshness of different types of fish food products. In many countries, there are established standards, guidelines and specifications for the evaluation of fish freshness based on the TVC index correlated with various storage conditions, temperature, time and atmosphere. This indicator is considered by some to be useful for accurately detecting the degree of freshness of fish and for predicting the remaining shelf life (Cheng et al 2015).

Raw fish contains its own unique flora, determined by the microbial content of the water in which it was raised, and which persists despite processing as food or further preservation by chilling (Jan et al 2014). The development of a model for the dynamics of microbial spoilage in shelf-life prediction introduced the concept of specific spoilage organisms (SSO), which allows the formulation of microbial spoilage models. SSO was defined as the part of the total microbiome (*Pseudomonas* spp., *Photobacterium phosphoreum*, *Shewanella* spp.) responsible for fish spoilage. Currently, the detection of SSO is accurate using the PCR method (Tahsin et al 2017).

However, micro-organisms are not an accurate way of determining fish quality, as different fish of similar quality can be found to have very different numbers of micro-organisms present depending on where they are caught or raised. In addition, as fish age, the number of microorganisms present will be higher, and, if a starting number is not known, it cannot be used as a reliable indicator of quality or spoilage. Traditional bacteriological examinations are laborious, time-consuming, expensive, and require skills in performing and interpreting the results. Thus, it is recommended that such tests be limited in number and scope (Torry Advisory Note no. 91, 1989).

Conclusions. In order to provide a good overview of the quality of the fish product and especially of the state of freshness, sensory and instrumental methods must be corroborated, because of their advantage. However, when singularly used, they also have many disadvantages.

Conflict of Interest. The authors declare that there is no conflict of interest.

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