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Quality Index Method for fish quality control: Understanding the applications, the appointed limits and the upcoming trends

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ABSTRACT

Background: The Quality Index Method (QIM) is a widely used approach for fish sensory grading, based on a structured scaling for freshness measurements, providing information concerning the fish freshness status, as a prediction of the remaining shelf-life for specific species or products. However, its tendency to be used in an oversimplified way and other common misapplications could lead to discredit of a methodology with great potential.

Scope and approach: Review the principles of QIM methodology, discussing its concept, applications, and understand their limits, as a useful strategy to propose improvements, reinforce its predictive power and consequent acceptability.

Key findings and conclusions: QIM methodology is based on a compromise between the number of fish samples necessary and the number of attributes, with sensory relevance in fish spoilage, that allows verifying if quality requirements are fulfilled. However, the assumptions inherent to the method, undermine the reliability of the shelf-life predictions. Determination of the variability associated with assessors, product, and correct structure of datasets for statistical analysis, will improve the predictive power of the method. However, it could lead to an increase in the method complexity that would drive it away from the industry's needs for fast and easily implemented methods.

1. Introduction

Consumers' demands for foods with high nutritional value or certain specific sensory properties (*e.g.*: appearance) are a result of consciousness of the impact of food products on their health, pleasure, or preference. All seafood products are associated to highly perishable products, mostly the ones that are to be sold as fresh products. Degradation of fish products is related to three main post-mortem processes, responsible for their main sensory changes: oxidation, microbial degradation, and autolysis. They are responsible for the evolution of spoiled fish, and for the development of specific substances that contribute to fish spoilage (Ghaly, Dave, Budge, & Brooks, 2010; Prabhakar, Vatsa, Srivastav, & Pathak, 2020). The knowledge of the evolution of various descriptors and properties associated with the spoilage process, allows the evaluation of fish optimal condition (after slaughter), as well the estimation of its capability to retain those sets of characteristics through time. The collection of this information could reflect the apparent elapsed time since the capture, contributing to the estimation of the rejection time for consumption (Gonçalves, 2010; Matos, Dias, Dinis, & Silva, 2017). In the case of fresh fish sold as a whole product, there is minimal industrial processing based on washing and consequent cold storage, more commonly in ice. Implementation of these procedures aims the inhibition of bacterial growth, enzymatic action, and oxidation, contributing to its freshness retention, safety, and shelf-life extension (Boziaris, 2014). Freshness and shelf-life assume crucial importance to industry and consumers, as they determine the product acceptability and, consequently, its commercial value. However, they are difficult terms to define due to their common basic principles, associated with food degradation and the methods used to study them (Barbosa, Bremner, & Vaz-Pires, 2002; Bernardi, Mársico, & de Freitas,

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2013; Bremner & Sakaguchi, 2000; Giménez, Ares, & Ares, 2012). Freshness is associated with an ideal condition of the product, related to the properties it had before capture/harvest or immediately after such activities and with methods used for evaluation (Freitas, Vaz-Pires, & Câmara, 2020; Matos et al., 2017). Shelf-life will be related to the duration of product conformity with label declaration, nutritional data, chemical, microbial, physical, and sensory characteristics, as well as with methods used to delay the impact of the post-mortem process and extend storage time (Ghaly et al., 2010; Wang, Zhang, Gao, & Adhikari, 2017).

Consumer decisions about a food product do not depend solely on the associated pleasure or its organoleptic properties (Claret et al., 2014; Matos et al., 2017). They are also dependent on personal expectations that vary among consumers as well as with the cultural or geographical influence (Conte, Passantino, Longo, & Voslářová, 2014; Ghisi & de Oliveira, 2016). In many cultures and countries, fish is frequently bought as a fresh whole product, with minimal labeling and without being packed. Since fresh fish is influenced by sensory changes (*e.g.*: appearance), also perceived by the buyers, it would help them made a more scrupulous choice in the purchase phase than at the consumption. This is normally credited to the idea that at the buying moment most consumers are considering storing the product for a period before consumption. At the expected consumption moment, they are more tolerant to defects to avoid wasting the product (Giménez et al., 2012; Østli, Esaiassen, Garitta, Nøstvold, & Hough, 2013). This scenario will influence the estimated product shelf-life. Instead of being related with sensory rejection due to unacceptable taste characteristics (maximum shelf-life), it will be based on alterations of other sensory attributes occurring in an early stage of fish degradation (product grading approach) (Ghaly et al., 2010; Prabhakar et al., 2020). Either way, this period is always smaller than the maximum shelf-life estimated for a fresh fish (Østli et al., 2013).

The determination of this middle point (rejection day), is normally of utmost interest for the fish industry. For industry, it is important to ensure the retention of the best characteristics during the time necessary for its distribution, acquisition, and consumption (Giménez et al., 2012). Consequently, the industry establishes the product shelf-life having in consideration the moment when the product is rejected by a percentage of the evaluation panelists, to which is subtracted a period that comprises the distribution, product purchase, and consumption. Also, at the industrial level, it might only be required to determine freshness, acceptance, or rejection on a basic level. Therefore, freshness characterization of fish products according to the factors of capture or post-production (handling, packaging/conservation, distribution) is of increasing relevance, to achieve better predictions of storage effects and distribution conditions on product shelf-life (Gonçalves, 2010). To avoid economic loss, the seafood industry should rely on accurate methods and procedures to ensure that the required quality parameters are met by all chain representatives (Hassoun & Karoui, 2017). The methods reflect the different species spoiling patterns and can be categorized in chemical analysis (*e.g.*: TVB-N and TMA analysis) (Prabhakar et al., 2020), microbial counts (Cheng, Sun, Zeng, & Liu, 2015), sensory analysis (Rehbein & Oehlenschläger, 2009), spectroscopic techniques (Hassoun & Karoui, 2017), and electronic sensors (Danezis, Tsagkaris, Camin, Brusic, & Georgiou, 2016). Some methods have common drawbacks such as being destructive and labor-intensive. Also, no single index can encompass all the complex changes occurring during spoilage (Martinsdóttir, 2010). However, they can complement each other and deliver acceptable estimations. Independently of the chosen method and the reasons behind it, sensory evaluations will remain a key factor, since sensory clues are the main parameters a consumer can follow when buying fresh fish. Therefore, any chemical or instrumental analysis that is developed or used, must be in agreement with sensory results. (Alasalvar, Shalidi, Miyaslita, & Wanasundara, 2011).

In Europe, it is usual to perform a sensory evaluation at different levels in the seafood industry such as after landing, at the fish plant and processing halls, or auction sites. Often fish is graded, priced, and sold based on freshness criteria accessed by fish inspectors using sensory analysis (Hyldig, Bremmer, Martinsdóttir, & Schelvis, 2010). For this purpose, specific sensory methods were developed for fish sensory analysis, with a special application in the industry but also with correlation to consumer acceptance. Such methods include the EU scheme, Torry sensory analysis, and Quality index Method (QIM) (Oehlenschläger, 2013, pp. 359–386). From these, QIM is more adaptable, once it is developed and validated, its application is fast, non-destructive on raw fish, is species-specific, allows direct measurement of the perceived attributes, estimation of the product shelf-life, and enables the collection of information for a better understanding of consumer responses (Nollet, 2012). Besides its general acceptance, several limitations have been pointed out, during its development phase and application, that could undermine its predictive power. Therefore, this work aims to review QIM basic principles, clarify its application and benefits, explain its limitations, and point out what its future could be.

2. Fish sensory quality control

The sensory investigation is performed to create predictions about how product alterations (arising from ingredients, processes, packaging, and aging/shelf-life), will be perceived by human observers. Sensory science is described as a quantitative discipline that uses the human senses (*e.g.*: vision, smell, or taste) for interpretation, measurement, and analysis of different environmental, physiological, processing, or conservation factors on food products characteristics (*e.g.*: appearance, odor/aroma, texture, flavor/taste) (Sharif & Sharif, 2017). To serve its purpose, the procedures for sensory evaluation must be very well defined. For proper result interpretation, a correct data analysis is critical. When a method has to be chosen the following conditions should be considered: the problem to be solved; the advantages it has; its accuracy, precision, and robustness; its adaptability to future requirements; its information value; its probability of adoption and costs; its correlation with actual knowledge and prediction capabilities (Civille & Oftedal, 2012).

The classical view about sensory analysis is that it can be associated with objective sensory questions (*e.g.*: performed in laboratories) influenced by food industry processes, and with consumer research, that deals with subjective parameters of quality (*e.g.*: led by marketing departments) (Lahne, 2016). However, it has as an objective to find answers for particular questions related to product quality perception. This topic has been discussed, in terms of its application in specific areas (*e.g.*: consumer research; marketing or shelf-life) and the methodologies appropriateness for stipulated objectives (Iannario, Manisera, Piccolo, & Zuccolotto, 2012; Lawless & Heymann, 2010; Stone, Bleibaum, & Thomas, 2012; Varela & Ares, 2012).

Frequent terms used in methods for seafood sensory analysis or quality control are scaling, ranking, and grading. However, in quality control, they can have similar meanings while in a pure sensory analysis approach they are different (Kilcast, 2010; Lawless & Heymann, 2010).

In ranking, an ordinal scale is utilized to put in order the intensity/degree of an attribute (*e.g.*: the color of smoked salmon). They are best fitted to research but not so suitable for industry quality control application (Carabante & Prinyawiwatkul, 2018). Scaling emphasizes differences and degrees of change, that are usually higher than the limit level or with a noticeable difference. A specific approach is category scaling, where the panelists are requested to rate the stimulus intensity by being trained with standards of different intensities (inexistence to excess). Grading is the application of a categorical value to a product lot or group. In sensory grading, the grader needs to integrate different perceptions being requested to rate the simultaneous effect of negative and positive attributes, the mixture or balance between them, and compare the products with physical or written standards (structured scaling). The conclusions are confirmed by the correlation of measurable chemical or physical properties with statistical analysis. The advantage of grading is that it allows the selection of products for different "qualities'' (Lawless & Heymann, 2010; Rehbein & Oehlenschläger, 2009).

From sensory science, the definition of grading is the one that integrates the industry perspective. However, the utilization of quality grading schemes should be done carefully. Common recommendations are to use it on products with a generalized consensus on its sector (*e.g.*: fish, dairy, and wine industry) (Kilcast, 2010).

For fresh fish, quality evaluation along the supply chain is governed by its sensory evaluation, frequently through the analysis of appearance and odor (Howgate, 2015). This marks a common point between industrial quality control and the consumer perspective on the product freshness that will influence his overall quality perception (Engle & Dey, 2017). Recognition of freshness and the identification of defective characteristics is the basis of sensory analysis of fresh whole fish and maybe all that is necessary for routine industry decisions. In this case, it is clear which are the ideal product characteristics and the common sensory defects that arise from poor handling, processing, or storage (Howgate, 2015). Therefore, it is in the industry's interest to make available, products that correspond to the common sensory criteria also perceived by the consumer, to increase the probability of selling its products. This approach is related to the fulfillment of the quality standards criteria, stipulated by regulatory entities, and also associated with grading methods (Kilcast, 2010; Nielsen, Hyldig, & Larsen, 2002).

The primary methods used for sensory fish quality control are presented in Table 1, even though others can be used in different steps of the supply chain (Nielsen et al., 2002). All of them have their strengths, weakness, and are used to rate, scale, or grade fish products (Hough & Garitta, 2012; Kilcast, 2010; Rehbein & Oehlenschläger, 2009).

2.1. Torry scale

The Torry scale is a detailed scheme for the freshness evaluation of cooked fish. It is frequently applied on cooked fish samples to evaluate odor and off-flavors, such as to establish the product's maximum shelf-life, which is determined when the eating qualities show evidence of off-flavors or taste. It is a descriptive scale of 10-points, developed for fat, medium fat, and lean fish. The value of 10 is considered the freshest fish possible. The limit for consumption is set at 5.5, at the value of 3 is considered spoiled and below this is considered unfit for consumption. Several adaptations of the scheme exist and are used by trained panels (Alasalvar et al., 2011). The method's drawbacks are the sample destruction and the time required for execution, which is not reliable for routine analysis in the industrial environment. However, the technique is correlated with other methodologies more suitable to industry requirements such as electrical conductivity, chemical, and microbial analysis (Cheng et al., 2015; Hassoun & Karoui, 2017; Ndraha, 2017, pp. 185–196). Therefore, it would be beneficial for the industry to have other methods that could also correlate very well with the ice storage time, but performed in whole fish, at early stages in the production chain, and capable to assist in product management (*e.g.*: shelf-life prediction).

2.2. European union scheme

The EU regulation (EC) No 2406/96, states the obligation to grade the product according to EEC guidelines at the first sale on landing points. According to it, all described fish species (whitefish, bluefish, selachii, cephalopods, and crustaceans) are categorized into 4 levels: E (Extra) – the highest level, A – good quality; B – acceptable for consumption; and C – unfit for consumption (Nielsen et al., 2002). A weakness of this method is that there is no specification for training, sampling, and other procedures, making it difficult to be reliable and reproducible without extensive experience. The usage of unspecific parameters for fish sensory description increases the probability of over-emphasis of one criterion as a discriminative parameter. Also, it does not consider species specific spoilage characteristics. The structure used does not allow to differentiate between intermediate points, since there are characteristics that are not described, or do not agree with the attributed grade (E, A, B, or C), influencing the amount of information provided in terms of shelf-life data, or to apply statistical analyses for reliability and reproducibility studies. Therefore the design of the EU scheme is not suitable for Quality Assurance control at the industry level (Martinsdóttir, 2010; Rehbein & Oehlenschläger, 2009). The EU scheme is also often misused in research studies as a structured scale, to which is applied arithmetic analysis (Cheng et al., 2015; Zavadlav et al., 2019). Despite the criticism, the scheme is still in use, and a useful multilingual glossary in 12 European languages for the EU grading scheme is available. It is better applied at the first sale to detect unacceptable fish, where fast decisions must be made, by experts and inspection authorities (Nollet, 2012; Oehlenschläger, 2013, pp. 359–386). However, quality grading in the industry requires a more reliable and useful tool to grade fish freshness. One suggested method is the Quality Index Method that overcomes some of the limitations attributed to the EU scheme, making it possible to establish a correlation between QIM results and the other available methodologies.

As an objective attribute scoring procedure, QIM is based on Soudan scales (Howgate, 2015). Its specific features are: a) the higher number of attributes evaluated (10–15), with specific alterations during storage; b) the use of short scales with different lengths (0–3), according to the

Table 1
Principal fish grading schemes. Differences, advantages and disadvantages.

Grading scheme	Product	Grading scale	Advantages	Disadvantages	Reference
EU scheme	Whole fish	E – extra A - good quality B - acceptable consumption C - unfit for consumption	Fish acceptability for consumption	Not species specific Mixes subjective and objective methods Cannot predict shelf-life	(Alasalvar et al., 2011)
Torry Method	Cooked or raw samples	10 - optimal condition 5.5 – limit for consumption <3 – unfit for consumption	Fish acceptability for consumption Maximum storage time Correlated with changes in electrical conductivity	Destructive	
Quality Index Method	Wole fish and raw fillets.	0 - optimal condition 1-2 - intermediate stage 3 - spoiled putrid	Fish acceptability for consumption Storage time prediction Remaining shelf-life prediction Time-temperature integration Species specific Non-destructive Evaluation based on multiple attributes No equipment required	Should be developed for each species	

number of perceptible changes in each attribute; c) the overall quality index (QI) obtained from the summation of the scores. QIM measures the rate of change in important attributes used to describe freshness, making it possible to relate them with time-temperature integration and shelf-life estimation (Hyldig et al., 2010; Hyldig & Green-Petersen, 2004; Martinsdóttir, Sveinsdóttir, Luten, Schelvis-Smit, & Hyldig, 2001). However, some doubts are also pointed out for the method, in relation to whether all the attributes scored are needed, or the impact of the variability attributed to the fish samples, and if the assessors' bias is adequately considered. Therefore, the merits and limits of the method will be reviewed in the following section (section 3).

3. Quality Index Method

QIM was originally developed by the Tasmanian Food Research Unit. It is a fast, simple, and non-destructive, descriptive method for seafood freshness evaluation. It provides all the users throughout the supply chain, with a standardized and reliable sensory measure of product freshness. Its standardization is supported by the ISO norms which are important in the development of new schemes and the establishment of common rules for research or industrial implementation (Hyldig et al., 2010; Martinsdóttir, 2010; Nollet, 2012). It allows collecting specific information about the fish condition during storage considering the differences between fish species (see Section 3.1). Also, once established and developed, QIM schemes are easier to use than some other methods and only require as much equipment as the human senses. QIM is an objective method, well suited to train, teach, monitor, and evaluate new or experienced panelists. The descriptors of quality are well defined and complemented with illustrations, in most of the schemes (Freitas, Vaz-Pires, & Câmara, 2019; Martinsdóttir et al., 2001).

The main disadvantages commonly associated with the method are: subjectivity connoted with sensory analysis; the time needed to train the personnel; and development of different schemes for each specific species or fish product (other specific limitations are discussed in section 3.3). It is necessary to refer that this sensory evaluation method has a well-established protocol for product evaluation and scheme development. Fig. 1 describes the main steps for the development of the QIM scheme.

When selecting and training judges for sensory analysis, it is important to be aware that some people might have natural limitation in tasting rancid flavors or iodine, possess low response to cold-storage flavor, or allergic reactions to different fish-proteins, shellfish, or histamine (Nollet, 2012). The utilization of truly specialized and trained panel members is important when the methodology is applied for new species or products, in which the QIM has to be rigorously established and validated, in order to be easily replicated by others (*i.e.*: factory workers). Once this validation is done, the implementation at companies or personal training is straight forward. The developed guidelines have only to be followed and checked. The analysis is based on specific and clear parameters, that suffer alterations during storage time, and any person (that does not have specific natural limitation) can detect them (Amaral & Freitas, 2013; Sharif & Sharif, 2017).

In the following sections, special attention will be given to the concept behind the QIM method (Section 3.1), the QIMs applications (Section 3.2), and the limitations appointed to the method (Section 3.3).

3.1. Concept

The implementation of good practices in the fisheries and aquaculture sector provided standardization of procedures (*e.g.*: temperature control) that allow the development of methods for expressing freshness, spoilage, or shelf-life. The proposition behind the QIM scheme is that evaluators cannot efficiently judge degrees of perfection but can very readily detect deviations or changes from it. This is due to the knowledge that during the storage of fish, changes occur, are detectable and often measurable.

The concept of the relative rate of spoilage states that most protein foods (*i.e.*: fish, meats, or milk) spoil at similar rates, expressed as a ratio to the rate they spoil at the reference temperature of zero degrees Celsius (0 °C). This means that spoilage at a variety of temperatures can be expressed in terms of equivalent days of storage at 0 °C and that the integrated effects of storage at different temperatures can be taken into account. It also results from the nature of this relationship, in the case of fish, that it spoils four times faster at 10 °C than at 0 °C, and twice as fast at 4 °C than at 0 °C (Hyldig et al., 2010; Nollet, 2012).

However, besides the importance of the time-temperature reference, such relation by itself is not sufficient to perfectly describe the fish freshness state (Bremner & Sakaguchi, 2000). This means that other

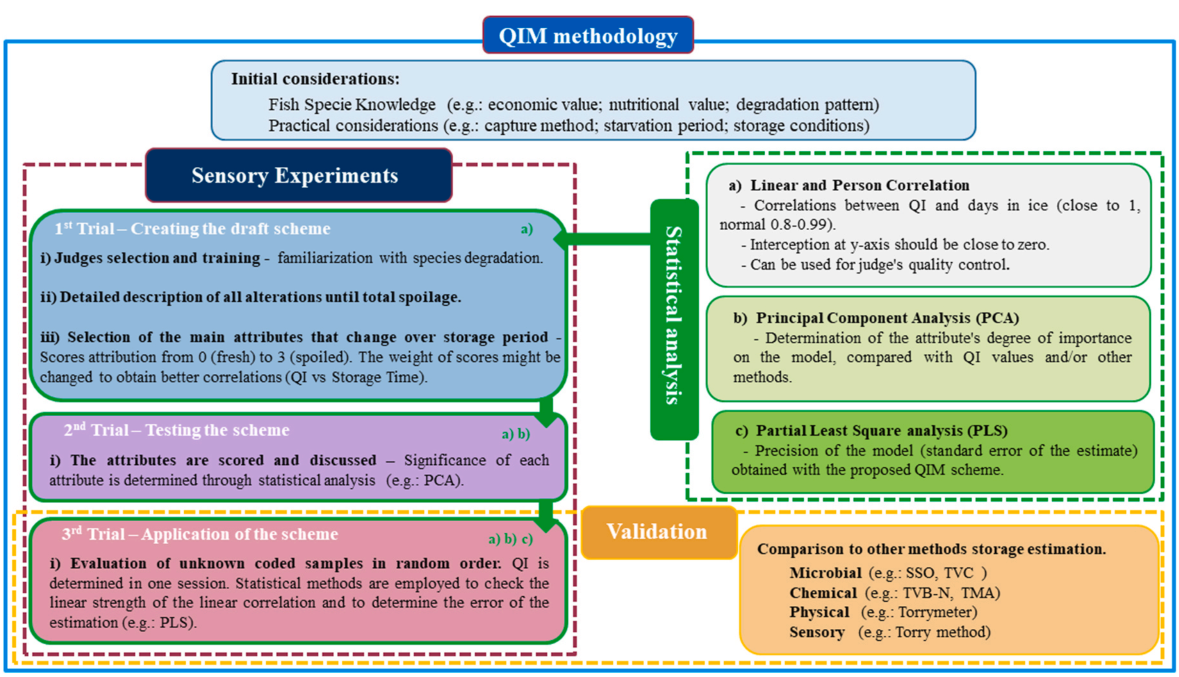

Fig. 1. Common steps for QIM development.

factors will also impact fish spoilage rates. In the case of aquaculture, the processes of pre-harvest (*i.e.*: starvation period), harvest (*i.e.*: slaughter method), and post-slaughter techniques (*i.e.*: evisceration) affect every major property of fish flesh (*i.e.*: texture or appearance) in the first few days of storage, contributing to the initial freshness state condition and its duration (Borderías & Sánchez-Alonso, 2011; Gonçalves, 2010). Therefore before QIM development, it is necessary to register the peri-mortal circumstances (Bremner & Sakaguchi, 2000). This knowledge will help to determine which conditions the scheme is better suited for application.

Having into consideration the previous pre-conditions, what the QIM measure is the rate and degree of alterations in important attributes during fish spoilage. Such attributes can be alteration in fish skin, mucus, smell, overall appearance, eyes, etc., (Fig. 2). In this system, all the attributes are evaluated in each fish following the same order; besides that, no importance is given to any particular aspect and, therefore, errors and incongruences associated with one attribute assessment are reduced (Martinsdóttir, 2010).

The resultant QIM scheme becomes a list of attributes, with associated parameters each with a specific change accompanied by a description. The terminology used for the description should state specific alterations related to a precise moment and not be dependent on previous or future states of the sample. Fig. 2 represents a novel sensory wheel for QIM methodology, presented and proposed for the first time in this review, with the most common evaluated attributes for fish and some commonly used terminology.

Demerit points are attributed to the defects encountered in the product, associated with each parameter. The scores are based on a scale from 0 to 3, being 0 the best condition possible, and 3 the worst. Also, the scoring allotted to each parameter is such that no single parameter could dominate and that the scores values are easy to judge. Since the individual attributes can have different degradation patterns (when plotted the scores *vs* storage days), the individual scores are summed to provide a total, an overall evaluation denominated as Quality Index (QI). The lower the total score, the fresher the fish. If, for example, the maximum of three demerit points are scored within the first five days, but it is generally known that the shelf life is, in total, about 14 days, the description per demerit point needs to be adjusted in such a way that the scoring covers more of the complete shelf-life (Martinsdóttir, 2010; Martinsdóttir et al., 2001).

To avoid scoring irrelevant criteria or the imprecision of using only one, proper statistical treatment of the selected criteria should be performed in order to select the ones that significantly contribute to the relationship between degradation progress and storage time (Bernardi et al., 2013; Bogdanović, Šimat, Frka-Roić, & Marković, 2012). Fig. 1 presents some of the most used methods for statistical treatment. Successful evaluation of QI models implies the following: the amount of data collected (number of selected attributes and data points) must be in sufficient number to give a possible score of reasonable magnitude (Nollet, 2012). The result obtained in the scheme can be used as an index of what the material should be for an appropriate end-use. A simple calculation can indicate: the equivalent to the number of days that the product has been stored at 0 °C; judge its ability to withstand a process; a particular grade of a product; or it may foreshadow what the product is anticipated to be like when it is acquired, cooked and eaten by the consumer (Martinsdóttir, 2010).

Although QIM is an important tool for the prediction of the commercial validity expiration or rejection time, the results should be supported by other assessment methods. Correlation between different techniques is becoming increasingly important in market development.

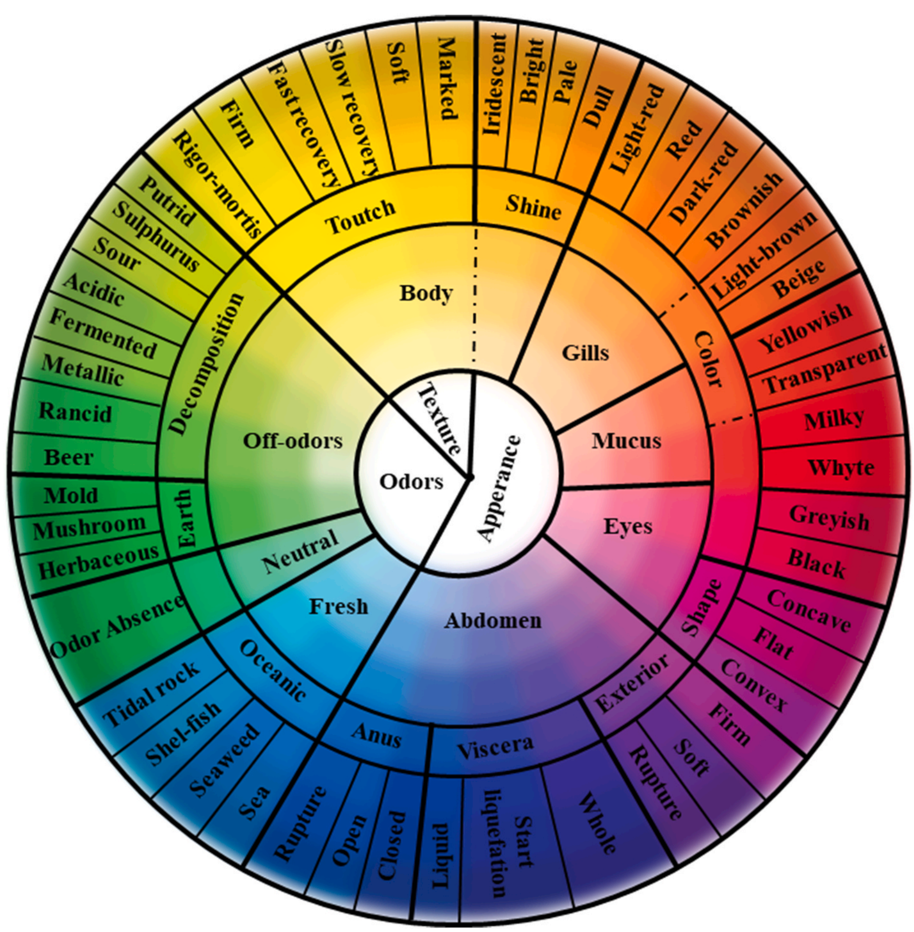

Fig. 2. QIM sensory wheel, with the most common attributes evaluated and terminology used.

Therefore, to properly validate a QIM scheme, it has been proposed that the method should be supported and correlated with other evaluation methods in a range of subjective (sensory), objective (non-sensory), and statistical methods, providing much more precise and realistic results (Freitas et al., 2019; Sant'Ana, Soares, & Vaz-Pires, 2011). Sensory methods such as the Torry method can be used to estimate the rejection point of QIM schemes (Gonçalves, 2010; Martinsdóttir et al., 2001). However, for its application, the form of the final product should be taken into consideration the form of the final product. This method is mostly applied to fillets, or for the same fish sold as a whole product since the rejection point in this form occurs sooner than for fillets (Sant'Ana et al., 2011). Objective methods such as chemical analysis (*e.g.*: Trimethylamine; TVB-N; K- value) are frequently used for freshness assessment of transformed fish products (Prabhakar et al., 2020). Even though, for some species they might not be perfectly suited for freshness evaluation, due to low increase during the first days of storage, they can be correlated with spoilage progress. Such methods quantify the number of specific chemicals (*e.g.*: volatile amines and ammonia) that are originated during decomposition or that increase in the same period (Howgate, 2010). Other methods could be the quantification during storage, of microbial activity through TVC counts or specific spoilage organisms (SSO). Also, the measurement of dielectric properties of fish muscle during spoilage is applied using instruments like the Torrymeter (Sant'Ana et al., 2011).

3.2. Applications

The QIM-EUROFISH project (www-qim-eurofish.com) has been important for the method dissemination, with a manual containing 13 QIM schemes as an example, published in multiple languages (Hyldig et al., 2010). There has been considerable publication effort demonstrating the continuous importance of QIM, with the development of schemes for new species and products from wild or farmed species, and also the optimization of previously published schemes. Table 2 summarizes the QIM schemes created or improved, in the scientific literature from 2012 until 2019. For the period before 2012 information is present on Barbosa & Vaz-Pires, 2004; Bernardi et al., 2013; Sant'Ana et al., 2011 and the QIM-EUROFISH database.

In this period QIM methodology has been routinely applied in most of the scientific works related to freshness or sensory analysis of seafood products. The works can be divided into three main study areas some examples are: first schemes for a specific species (Billar dos Santos, Kushida, Viegas, & Lapa-Guimarães, 2014; Fogaça et al., 2017; Freitas et al., 2019; Lanzarin et al., 2016; Mayrla et al., 2017; Ritter et al., 2016), the impact of storage conditions (Andrade et al., 2015; Manimaran et al., 2016; Mu, Bergsson, & Thorarinsdóttir, 2017; Ochrem, Zapletal, Maj, Gil, & Zychlińska-Buczek, 2014; Pinter, Maltar-Strmečki, Kozačinski, Njari, & Cvrtila Fleck, 2015) and type/formulation of products (Li, Li, et al., 2012; Li, Li, Hu, & Li, 2013; Özogul, Tugce Aksun, Öztekin, & Lorenzo, 2017). Other areas are, the effect of rearing conditions and harvest methods (Badiani et al., 2013; Daniel et al., 2014; Gonçalves, Emerenciano, Ribeiro, & Neto, 2019; Olsen, Tobiassen, Akse, Evensen, & Midling, 2013), post-harvest procedures (Churchill, Fernandez-Piquer, Powell, Shane & Tamplin, 2016; Roiha et al., 2018) and feed formulation studies (Castro, Rincón, Álvarez, Rey, & Ginés, 2018; Ozório et al., 2016; Öz, 2018).

Some examples can be found, in which QIM methodology was used as support for the development of new freshness sensors, as a control method to verify the sensors results (Brizio, Gonzaga, Fogaça, & Prentice, 2015; García et al., 2017).

Ice storage is still the most studied preservation method, probably resulting from the fact that it is the most used method for the product presentation to the consumer. This means that QIM is an increasingly important methodology for the determination of deterioration progress of fish sold as fresh. Other storage conditions and packaging techniques have also been studied, with an emphasis on modified atmosphere (Bono & Badalucco, 2012; Cyprian et al., 2012; Gornik, S.G., Albalat, A., Theethakaew, C., Neil, 2013), vacuum (Fuentes-Amaya, L., Munyard, S., Fernandez-Piquer, J., Howieson, 2016; Zhang et al., 2016), gels (Li, Li, et al., 2012; Qiu, Chen, Liu, & Yang, 2014) or emulsions formulation (Castro et al., 2015; Shadman, Hosseini, Langroudi, & Shabani, 2017; Özogul, Durmus, Ucar, Özogul, & Regenstein, 2016). The type of product studied vary between whole fish, gutted/eviscerated, and fillets, reflecting the main method of presenting the product to the buyers, according to each region. In the early stages of the method, it was mostly applied in species widely consumed in Europe (*e.g.*: salmon, trout, seabream). Now the targeted species or type of product for QIM studies are the ones with increasing regional economic importance, the ones being studied for aquaculture diversification, or the ones that have the potential to be exported.

One of the main reasons to develop QIM studies is to establish an estimation for the product shelf-life based on human sensory perception (Table 2). Its, ease of use and correlation with other methods (*e.g.*: microbial and chemical analysis) helps it to be the complementary sensory method of choice for raw, whole, fresh fish analysis. The most common results for shelf-life estimation in ice storage vary between 8 and 17 days, with the lowest value referred to as 2 days (Furlan, 2013) and the highest as 35 (Daniel et al., 2014). These estimations should be used with precautions, not only because of fish shelf-life being highly dependent on species but also due to uncertainty associated with the method (see section 3.3).

Since the EU recommendation is still the EU scheme a correlation table between QIM values and EU methodology was developed (Nollet, 2012). As it became accepted and established in European countries, it is possible to see that now its application is being adopted in different regions of the globe, reflecting the impact of quality control methodologies applied in Europe, one of the biggest fish consumer markets.

3.3. Appointed limits and pitfalls

As in any methodology, QIM has its drawbacks. Most of the common limitations are the ones attributed to general sensory analysis and among them are: costs, time-consuming, and the need of expert personnel (Ares, 2015). All of them are true for the development of QIM schemes for new species or to new product conditions, as well as for other methods normally defined as traditional methods (Freitas et al., 2020; Hassoun & Karoui, 2017).

The most recurrent issue in the QIM literature that affects the method strength, is the confusion between the used terminology and the lack of compliance with the best practices for sensory evaluation. In the last case, the most common are the number of assessors used and the number of training sessions (Galanakis, 2019). Other cases that arise from the search results about QIM publications are that some of them use the QIM terminology, but in the execution phase, it seems like a quality descriptive analysis (QDA). Most of them, state the development of a quality index scheme but the attributed values vary between 1 and 5 or 0–4, and in other cases, the higher scores are given to the fresher samples (Álvarez, García García, Jordán, Martínez-Conesa, & Hernández, 2012; Ebadi, Khodanazary, Hosseini, & Zanguee, 2019; Gonçalves & Santos, 2019; Hernández, García García, Jordán, & Hernández, 2015; Lahreche, Uçar, Kosker, Hamdi, & Ozogul, 2019; Navarro-Segura, Ros-Chumillas, López-Cánovas, García-Ayala, & López-Gómez, 2019; Yu, Jiang, Xu, & Xia, 2017). Even though some authors refer that the original method was altered, it is necessary to consider the correct usage of the terminology, to not hamper the implementation of QIM methodology or arise misconceptions about the method.

However, it is necessary to acknowledge other method limitations, for it to be efficiently applied and not undermine the benefits that are possible to be gainned from its use. Along the following subsections, different limitations of the QIM methodology will be discussed.

Table 2
Applications of QIM scheme reported in literature between 2012 and 2019.

Species	Product	Storage Conditions	Total demerit point	Shelf-life (days)	Country	Ref.
Chelon subviridis	Fresh	4 °C	34	12	Iran	Kuvei, Khodanazary, and Zamani (2019)
Dicentrarchus labrax	Fillets & Nanoemulsions	Vacuum Package (2 °C)	18	14–16	Turkey	Durmus et al. (2019)
Mugil cephalus	Eviscerated	Ice	25	15	Brazil	Godoy et al. (2019)
Trachinotus falcatus	Whole & Gutted	Ice	18&11	18	Vietnam	Erikson et al. (2019)
Octopus insularis	Whole & Eviscerated	2 °C	24	15 & 20	Brazil	Aragão, Garruti, Ogawa, Bezerra, and Da Silva (2019)
Litopenaeus vannamei	Whole	Ice	36	9	Brazil	Gonçalves et al. (2019)
Gadus morhua *Salmo salar*	Whole & fillets	Ice (2 °C)	18 &15	8 10	Ireland	Fogarty, Smyth, Whyte, Brunton, and Bolton (2019)
Lagocephalus guentheri	Fillets	2 °C	14	10	India	Sreelakshmi et al. (2019)
Seriola dumerili	Whole	Ice (0 °C)	25	12	Portugal	Freitas et al. (2019)
Metapenaeus affinis	Whole	Ice	18	9	Iran	Khodanazary (2019)
Rhabdosargus sarba	Whole	Ice	34	9	Iran	Shalhe, Khodanazary, and Hosseini (2018)
Oncorhynchus mykiss	Whole & fillets	−18 °C	20	–	Turkey	Öz (2018)
Pagellus bogaraveo	Whole	Ice (4 °C)	30	–	Spain	Castro et al. (2018)
Oncorhynchus mykiss	Whole Gutted	Ice (2 °C)	30 15	12 14	Turkey	(Diler & Yüksel Genç, 2018)
Gadus morhua	Fillets	−28 °C	14	6	Norway	Roiha et al. (2018)
Pollachius virens	Fillets	2 °C	14	9–10	Iceland	Mu, Jonsson, Bergsson, and Thorarinsdottir (2017)
Oncorhynchus mykiss	Fillets & Nanoemulsion	Ice	16	17	Turkey	Özogul, Tugce, Öztekin, and Lorenzo (2017)
Rachycentron canadum	Whole	Ice (17 °C)	23	15	Brazil	(Fogaça et al., 2017)
Gadus morhua	Gutted	Ice	23	–	Spain	García et al. (2017)
Oncorhynchus mykiss	Fillets & oil nanoemulsion	(4 °C)	9	15	Iran	Shadman et al. (2017)
Colossoma macropomum	Eviscerated	Ice (0 °C)	34	22	Brazil	Araújo, De Lima, Peixoto, and Lourenço (2017)
Scophthalmus maximus	Whole	4 °C	20	15	China	Li et al. (2017)
Penaeus monodon	Whole	Ice	21	10	Vietnam	Le, Doan, Nguyen Ba, and Tran (2017)
Engraulis encrasicolus	Fillets & Plant Extracts	Vacuum Package (2 °C)	19	12	Turkey	Ozogul et al. (2017)
Pseudoplatystoma corruscans	Whole	Ice	16	13	Brazil	Mayrla et al. (2017)
Thunnus albacares	Frozen Steaks	4°c	10	8	China	Miao, Liu, Bao, Wang, and Miao (2017)
Lethrinus sp *Lutjanus malabaricus* *Lutjanus erythropterus* *Lates calcarifer*	Fillets	Vacuum Package (4 °C)	10 11 11 10	5	Australia	Fuentes-Amaya, Munyard, Fernandez-Piquer, and Howieson (2016)
Sparus aurata	Fillets & Limonene	Vacuum Package (2 °C)	8	15	Italy	Giarratana et al. (2016)
Scophthalmus maximus	Whole, gutted	Vacuum Package (4 °C)	19	16	China	Zhang et al. (2016)
Dicentrarchus labrax	Fillets & Nanoemulsion	(2 °C)	16	8–10	Turkey	Özogul et al. (2016)
Oncorhynchus mykiss	Whole	Ice	14	10	Portugal	Ozório et al. (2016)
Pseudoplatystoma fasciatum × *Leiarius marmoratus*	Eviscerated	Ice	18	12	Brazil	Lanzarin et al. (2016)
Cistopus indicus	Deskinned	Ice (5 °C)	16	12	India	Manimaran et al. (2016)
Cyprinus carpio	Eviscerated	Ice	19	18	Argentina	Agüeria, Sanzano, Vaz-Pires, Rodríguez, and Yeannes (2016)
Colossoma macropomum × *Piaractus brachypomum*	Eviscerated	Ice	18	10	Brazil	Ritter et al. (2016)
Salmo salar	Gutted	0 °C-15 °C	23	15–2	Australia	Churchill, Fernandez-Piquer, Powell, and Tamplin (2016)
Panulirus argus	Whole	Ice	15	10	Brazil	Gonçalves, de Lima, and de Paula (2015)
S. scombrus	Whole	Irradiated UV; 4 °C	20	4–5	Croatia	(Pinter, Maltar-Strmečki, Kozačinski & Njari, & Fleck, 2015)
Merluccius merluccius	Gutted	3 °C	19	5–8	Spain	García et al. (2015)
Sardina pilchardus	Fillets	Vacuum package	18	17	Algeria	Houicher, Kuley, Özogul, and Bendeddouche (2015)
Sparus aurata	Fillets	Ice	–	16–17	Spain	Castro et al. (2015)
Anguilla anguilla	Fillets	Vacuum package & refrigerated	18	12	Turkey	(Ozogul et al., 2014)l
Scophthalmus maximus	Raw Whole	Ice	30	16	Norway	Roth et al. (2014)
Cyprinus carpio	Gutted & Ungutted	4 °C	33	8	Poland	Ochrem, Zapletal, Maj, Zygmunt, & Zychlińska-Buczek (2014)
Rhamdia quelen	Whole	Ice	28	35	Brazil	Daniel et al. (2014)
Lateolabrax japonicas	Fillets	Chitosan Coat	12	12	China	Qiu et al. (2014)
Colossoma macropomum × *Piaractus mesopotamicus*	Eviscerated	Ice	26	11	Brazil	Borges, Conte-Junior, Franco, Mársico, and Freitas (2014)
Cynoscion acoupa	Eviscerated	Ice	23	8–9	Brazil	(Billar dos Santos et al., 2014)
Engraulis encrasicolus	Fillets	Ice	19	12	Algeria	Bensid, Ucar, Bendeddouche, and Özogul (2014)
Piaractus mesopotamicus	Eviscerated	Ice	32	11	Brazil	Borges, Conte-Junior, Franco, and Freitas (2013)
Xiphopenaeus kroyeri	Whole	Ice	11	2	Turkey	Furlan (2013)

(*continued on next page*)

Table 2 (*continued*)

Sparus aurata	Fillets & Limonene	Vacuum Package (2 °C)	8	15	Italy	Giarratana et al. (2016)
Nephrops norvegicus	Gutted	MA-Packing	14	9	U.K.	Gornik, Albalat, Theethakaew, and Neil (2013)
Sepia officinalis	Whole	Ice	20	6	Italy	Badiani et al. (2013)
Rachycentron canadum	Gutted	Ice	25	>15	Norway	Mach and Nortvedt (2013)
Ctenopharyngodon idellus	Fillets	Ice (2 °C)	14	12	China	Zhu, Ruan, Li, Meng, and Zeng (2013)
Gadus morhua	Fillets	–	8	–	Norway	Olsen et al. (2013)
Oreochromis niloticus	Deskinned Fillets	1 °C	13	15	Iceland	Cyprian et al. (2012)
		-1 °C		20		
		MA-packed		23		
Mullus surmuletus	Whole	Omap Map	13	15	Italy	Bono and Badalucco (2012)
Pseudosciaena crocea	Whole	Chitosan	33	19	China	Li, Hu, et al. (2012)
Boops boops	Whole	Ice	20	12–17	Croatia	Bogdanović et al. (2012)
Carassius auratus	Whole	Ice (0 °C)	22	13–15	China	Li, Hu, et al. (2012)
Gadus morhua	Fillets	Ice	13	5	Norway	Hultmann, Phu, Tobiassen, Aas-Hansen, and Rustad (2012)
Sardinella aurita	Fillets	Vacuum & zeolite	18	12	Turkey	Kuley et al. (2012)

3.3.1. Quality specifications and tolerance limits

The utilization of QIM methodology requires a definition of what is the quality parameters that have to be assessed and their tolerance limits. Fish freshness characteristics are well studied and established throughout the supply chain (Howgate, 2015). Therefore, they are well established and accepted not only on sensory analysis but also in chemical and microbial methods (Freitas et al., 2019). However, is necessary some attention for the establishment of these limits. It is necessary to consider the method applicability, the type of product, the company or client standards. The limit should not be arbitrarily applied or being simply inferred as the mean value of the QI values (Galanakis, 2019).

3.3.2. Assessors variability

One of the principal limitations attributed to QIM is that being considered a rapid methodology, is possible to be used by factory personnel or semi-trained assessors, which challenges the reliability of the results, due to variability associated with each assessor (Ares, 2015; Galanakis, 2019; Lawless & Heymann, 2010). Other sources of bias affecting sensory analysis panelists can be divided into psychological (*e.g.*: memory effect and concentration) and physiological (*e.g.*: age and nutritional health) effects (Sharif & Sharif, 2017).

Kilcast (2010) described some of the steps for panelist recruitment, training, and proficiency test, emphasizing the implementation of sensory quality control schemes in organizations (Kilcast, 2010). Such approaches are relevant to decrease the probability of biased results from the sensory test outcomes. Lawless and Heymann (2010) reviewed some of the methodologies for panel performance analysis, which can be univariate (*e.g.*: mean square errors (MSE)), multivariate (*e.g.*: principal component analysis (PCA)), or with the use of computational programs (*e.g.*: Panel Check) (Lawless & Heymann, 2010). Variability measurement is important not only for panel control but also for shelf-life estimation as will be discussed in further sections.

3.3.3. Product variability

Product variability is normally attributed to the product's intrinsic conditions (*e.g.*: nutritional composition and autolysis processes) or external effects (*e.g.*: season, killing, handling) (García et al., 2017). The measurement of these product variations is based on other methods referred to as traditional methods that encompass the chemical, physical and microbial analysis approach. Besides none of these approaches being a perfect choice, such measurements can provide valuable information about the fish freshness state (Joshy et al., 2020).

Variation of results (QI values vs storage time), for the same species, can demonstrate the impact of storage conditions, product formulation, packaging, handling, and killing on the development of sensory attributes during the degradation process. It is relevant to state that normally QIM schemes are compared with other methods for results validation, such as chemical, microbial, textural, or sensory. Ndraha (2017, pp. 185–196) reviewed the correlation between sensory, microbial, and chemical analysis on fish degradation. All these methodologies have established their legal maximum limits, from which the products are considered unacceptable for consumption. When the results are compared between different methodologies, it is possible to see the influence of each biological process on product rejection. As a consequence, some parameters could deteriorate at different rates due to microbiological and/or chemical activity, being of importance the appropriate choice of methods to obtain more concise results (Ndraha, 2017, pp. 185–196).

The external effects have also been studied using the QIM methodology (Cyprian et al., 2012). Taking the example of the effcet of washing on fish shelf-life there are different opinions, regarding whether the QIM approach is reliable enough to consider such impacts, because they can lead to misinterpretations when used for predictive purposes, indicating longer or shorter shelf-life (Arvanitoyannis, Tsitsika, & Panagiotaki, 2005; García et al., 2017). Therefore, it is not unusual for QIM schemes for the same species to present some variability in their results (Giuffrida, Valenti, Giarratana, Ziino, & Panebianco, 2013). For some species the methods used for validation, for example, chemical analysis, may not be 100% correlated with sensory analysis, due to specific endogenous characteristics of the fish species under study (Ndraha, 2017, pp. 185–196). However, it is still important to perform such methodologies not only to determine for which species they are fitted but also to increment the knowledge about the occurrence of such differences.

3.3.4. Data analysis

The common procedures for QIM data analysis are regression analysis of the scores and storage time, followed by verification/validation through PCA and PLS analysis. The utilization of the statistical methods is dependent on the questions to be answered and how the data is structured. In the QIM case, the main objective is to verify the suitability of the selected attributes to describe the spoilage evolution, their correlation with storage time, and determine the efficiency of the prediction. The importance of statistical treatment, the conditions for their application, and associated limits have been extensively reviewed. Lawless and Heymann (2010) and O'Mahony (1986), give a very extensive and structured analysis of statistics applied to sensory analysis (Lawless & Heymann, 2010; O'Mahony, 1986). Galanakis (2019) and Kilcast (2010), approached similar topic but under the quality control programs perspective (Galanakis, 2019; Kilcast, 2010), while Rossini et al., (Rossini, Verdun, Cariou, Qannari, & Fogliatto, 2012) and Pedro and Ferreira (Pedro & Ferreira, 2006) emphasize the application of PCA and PLS in sensory studies.

In terms of predictive model utilization of the QIM approach have some faults due to assumptions that are made. For example, the assumption that the zero-temperature is maintained throughout the storage does not correspond to a real-world condition, since it is known that temperature variations are common and have an impact on product quality (Mendes, 2019; Şengör, Balaban, Ceylan, & Doğruyol, 2018). Also, it is a punctual/categorical count analysis carried out in a specific time, and the predictions based on these conditions are not the most reliable, since they occur in a pre-determinate experimental environment, resulting in static correlation result (most probable prediction), limiting its predictive capability (García et al, 2015, 2017; Giuffrida et al., 2013). Other common setbacks are related to the importance, or weightage, that is allocated to each evaluated attribute, that due to the summations of the scores gain some redundancy (Costell, 2002; Joshy et al., 2020).

It is important to refer that the QIM method only do a prediction of the shelf-life under its specific conditions and is best suited for the industrial environment where quick decisions have to be made. However, the outcome of QIM methodology has its importance on the predictive models for shelf-life determination and is frequently integrated into the model's equations. This specific area of shelf-life estimation, through mathematical models, solves some of the common hurdles associated with the QIM methodology (Giménez et al., 2012; Guerra, Lagazio, Manzocco, Barnabà, & Cappuccio, 2008; Hough & Garitta, 2012).

4. Future improvements and trends

In the last years, a great effort has been made to spread the QIM methodology as a reliable and standardized method, to be adopted in the seafood chain. Different European projects were established to spread knowledge throughout the entire supply chain (Luten et al., 2003). However, a new and recent study might be needed to determine at which level the method is in action and how the information is being used. In the investigation area, the method is well established, being also common in seafood quality courses (Hyldig, G., Bremmer, E., Martinsdóttir, E., Schelvis, 2010).

The consumer QIM (C-QIM) scheme was also developed, not as an acceptance test, but as a decision tool to support the purchase of the product at fish markets (Alasalvar, C., Shalidi, F., Miyaslita, K., Wanasundara, 2011; Hyldig, G., Bremmer, E., Martinsdóttir, E., Schelvis, 2010). The correlation of QIM knowledge and methodologies for consumer studies (*e.g.*: CATA) has been also studied, to determine the common ground between both approaches and reduce the gap between consumers opinion, researchers, and market players (Calanche, Beltrán, & Hernández Arias, 2019; Godoy, Veneziano, Rodrigues, Enke, & Lapa-Guimarães, 2019).

The creation of the app ''How fresh is your fish'' in 2013 was an excellent initiative to reach the consumer (www.qim-eurofish.com). However, stagnation seems to exist in terms of the available species and integration of new ones, or the adaptation to more consumed species in each country. With the appearance of new QIMs and new partnerships, it might be possible to create a more robust database with the species organized by relevance for each country, markets demand, and other pertinent information (Luten et al., 2003). More studies about the effective implementation of the method could also be important, as the one performed by Indian researchers, at the Veraval fish landing center, where it was followed the process of fish freshness evaluation and grading, using QIM and the Torrymeter (Solanki, Parmar, Parmar, Parmar, & Masani, 2016).

The evolution of integrative systems for quality control lead to the proposal of sensory analysis systems applied to the total fish supply chain. The main purpose is to spread the communication about sensory results between main players throughout the supply chain. QIM approach can be applied all over the supply chain and further contribute to quality improvement from catch to the final consumer (Green-Petersen, 2010; Nollet, 2012). In the case of E-commerce platforms and electronic auctions, QIM methodology will have an impact as an integrated part of the quality evaluation. The development of digital technologies (*e.g.*: blockchain methodologies) will allow the integration of information relative to several quality parameters throughout the supply chain (Cook, 2018). The safety associated with the blockchain can reduce information errors and uncertainty between supply chain participants, making available information about the product that in other ways is difficult to access (Freitas et al., 2020).

The recent developments achieved by the biosensors (*e.g.*: enzyme biosensor), sensory bionic technologies (*e.g.*: e-tongue), spectrometric techniques (*e.g.*: Vis/NIR), and time-temperature sensors (TTI), will facilitate the transference of information related with the fish freshness and spoilage, to on-line platforms. Also, it has the potential to surpass some of the limitations associated with the conventional approaches (*e.g.*: subjectivity and repeatability) and contributes in the future understanding of degradation processes and the impact on sensory evaluation (Wu, Pu, & Sun, 2019; Zaukuu, Bazar, Gillay, & Kovacs, 2019; Şengör et al., 2018).

A holistic overview of the influence between different factors could be obtained through more studies, following a metanalysis approach as performed by Batista (2012). It would help to shed light on the possibility of integration of different QIM schemes under different categories of products or species, as proposed by Shabani and his coworkers. They suggest the utilization of a QIM scheme for salmonids. The hypothesis was tested through the application of a salmon (*Salmo salar*) QIM scheme in the rainbow trout (*Oncorhynchus mykiss*) shelf-life estimation. They concluded that a similar rejection time for trout was achieved with both schemes, therefore a QIM scheme for salmonids is possible to developed (Shabani, Beli, & Rexhepi, 2019).

New study areas for the QIM application will also be driven by the mathematical modeling of fish degradation. The first steps were given with the development of the Food Spoilage & Safety Prediction software (FSSP - (http://fssp.food.dtu.dk/), (Dalgaard, Buch, & Silberg, 2002)) updated in 2014. The integration of several predicting models approaches will continue to contribute to QIM development, leading to new finds and a better understanding of the degradation process (Alasalvar, C., Shalidi, F., Miyaslita, K., Wanasundara, 2011; Antunes-Rohling et al., 2019; Hyldig, G., Bremmer, E., Martinsdóttir, E., Schelvis, 2010). Also, it would help to overcome some of the associated limits of the method (section 3.3.), turning it into a more robust approach, not only for the fish sector but also for research purposes (García et al., 2017; Joshy et al., 2020; Rehbein & Oehlenschläger, 2009).

5. Final remarks

The application of food quality control systems, in the sensory analysis field, brings up questions related with the selection of properties or characteristics to be measured and the choice of methods. In this work, the merits and demerits of the QIM approach are reviewed. Most of the analysis performed under fish freshness analysis or spoilage determination, are limited by the ''one variable effect'' (*e.g.*: chemical), lacking sometimes the consideration of the holistic view of the synergies between the other remaining variables (*e.g.*: autolysis, microbial, or sensory). In this case following the idea of the sequential effect, the sensory analysis could be the last step of the chain since it tries to evaluate the simultaneous effect of the other parameters, even though they might not have an ordered sequential evolution.

Progress has been made in identifying and measuring freshness or spoilage parameters and certain quality-related criteria, but the promise of novel, fast, and cost-effective methods, might be closer for the bigger players and research facilities, than for the small and medium enterprises, in which the use of the current approaches will remain the nearest possibility (Oehlenschläger, 2013, pp. 359–386).

Even though, the common approach in the research field is to separate the methodologies according to their source (chemical, sensory, microbial), the rise of the chemometrics analysis, as well mathematical modeling, will improve the limitations between methodologies, allowing each approach to find its space at research and industrial level.

In the specific case of QIM methodology, once the most costly steps are surpassed (development and validation), it remains a suitable response, that allows achieving a compromise between the number of samples necessary and the list of characteristics, that allow simplicity into to check if the measured differences fulfill quality grade requirements, with enough precision for the industry where quick and cost-effective decisions have to be made (Borresen, 2008).

The recognition of the method limitations will allow proper data analysis and avoid doubtful conclusions to be made. The proposed improvements on the method, based on the statistics and mathematical modeling will increase its reliability and predictive power, contributing to the standardization of procedures and seafood supply chain improvements.

CRediT authorship contribution statement

Jorge Freitas: Conceptualization, Methodology, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Paulo Vaz-Pires:** Conceptualization, Methodology, Resources, Writing – review & editing, Visualization, Supervision. **José S. Câmara:** Methodology, Resources, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they do not have competing interests.

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