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Development of a quality index method (QIM) sensory scheme and study of shelf-life of ice-stored blackspot seabream (*Pagellus bogaraveo*)

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ABSTRACT

The aim of this work was to develop a quality index method (QIM) scheme for whole ice-boxed refrigerated blackspot seabream and to perform shelf-life evaluations, using sensory analysis, GR Torrymeter measurements and bacterial counts of specific spoilage organisms (SSO) during chilled storage. A QIM scheme based on a total of 30 demerit points was developed. Sensory, physical and microbiological data were integrated and used to determine the rejection point. Results indicated that the shelf-life of blackspot seabream is around 12–13 days.

1. Introduction

The definition of quality is very complex within the food industry. In the literature it is very common to find a mixture of quality, the concept, with quality, the measurement or attribute (Bremner, 2002, chap. 10). Botta (1995) defined some main quality attributes with respect to seafood: safety, nutritional characteristics, availability, convenience, integrity and freshness. The most important methods to evaluate freshness of seafood are the sensory methods (Bonilla, Sveinsdóttir, & Martinsdóttir, 2007). Freshness loss of seafood is the result of postmortem biochemical, physicochemical and microbiological processes characteristic of each species and influenced by handling on board and on land and by technological processing (Huidobro, Pastor, & Tejada, 2000). These changes are perceived and can be evaluated in sensory terms by sight, touch, smell and taste (Huidobro et al., 2000).

The Quality Index Method (QIM), originally developed by the Tasmanian Food Research Unit (TFRU), is a descriptive, fast and simple method to evaluate the freshness of seafood (Huidobro et al., 2000). This seafood freshness grading system (Sveinsdóttir, Martinsdóttir, Jorgensen & Kristbergsson, 2002) is based on significant sensory parameters for raw fish and a score system from 0 to 3 demerit points (Barbosa & Vaz-Pires, 2004; Branch & Vail, 1985; Bremner, 1985; Larsen, Heldbo, Jespersen, & Nielsen, 1992). It evaluates sensory parameters and attributes that change most significantly, in each species, during degradation processes (Huidobro et al., 2000). Therefore higher scores are given as storage time progresses.

Each fish species has its own characteristic spoilage patterns and indicators, and consequently QIM schemes must be species-specific (Hyldig & Green-Petersen, 2004; Nielsen & Green, 2007; Sveinsdóttir, Martinsdóttir, Hyldig, Jorgensen, & Kristbergsson, 2002). Barbosa and Vaz-Pires (2004) compiled a list of the QIM schemes available. At the time, 21 different fish species or products had specifically designed QIM schemes, while between 2002 and 2009 additional QIM schemes were built for 16 new seafood items. Table 1 summarises the schemes that were created and made available in the scientific literature within that period. In the second period (2002–2009), some of the schemes proposed for the first 21 species were repeated and/or corrected; these recent advances and new schemes can be found on the site of the international project QIM-EUROFISH (www.qim-eurofish.com).

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Table 1
Species with QIM tables developed in 2002–2009 and corresponding bibliographical sources (for QIM references older than 2002, see Table 1 at Barbosa & Vaz-Pires, 2004).

Common name	Scientific name	Product	References
Artic charr	*Salvelinus alpinus*	Raw, whole, farmed	Cyprian, Sveinsdóttir, Magnússon, and Martinsdóttir (2008)
Atlantic halibut	*Hippoglossus hippoglossus*	Raw, gutted, farmed	Guillerm-Regost et al. (2006)
Australian sardines	*Sardinops sagax*	Raw, whole	Musgrove, Carragher, Mathews, and Slattery (2007)
Black scabbard	*Aphanopus carbo*	Raw, whole	Nunes et al. (2007)
Broadtail shortfin squid	*Illex condetii*	Raw, whole	Vaz-Pires and Seixas (2006)
Cuttlefish	*Sepia officinalis*	Raw, whole, washed	Vaz-Pires and Seixas (2006)
	Sepia officinalis	Raw, whole, unwashed	Sykes et al. (2009)
Eel	*Anguilla anguilla*	Raw, gutted, farmed	Özogul, Özyurt, Kuley, and Polat (2005)
Flounder	*Paralichthys patagonicus*	Raw, whole	Massa, Palacios, Paredi, and Crupkin (2005)
Frigate tuna	*Auxis thazard*	Raw, whole	Ariyawansa, Wijendra, and Senadheera (2003)
Hake or Mediterranean hake	*Merluccius merluccius*	Raw, whole	Baixas-Nogueras, Bover-Cid, Veciana-Nogués, Nunes, and Vidal-Carou (2003)
Hybrid striped bass	*Morone saxalis x Morone chrysops*	Raw, whole, farmed	Nielsen and Green (2007)
Octopus	*Octopus vulgaris*	Raw, whole	Barbosa and Vaz-Pires (2004)
Sea bass	*Dicentrarchus labrax*	Raw, whole, wild, farmed	Alasalvar et al. (2002)
Shrimp	*Litopenaeus vannamei*	Raw, whole, farmed	Oliveira (2005)
Silver scabbard	*Lepidopus caudatus*	Raw, whole	Nunes et al. (2007)
Senegalese sole	*Solea senegalensis*	Raw, whole, farmed	Gonçalves et al. (2007)

This considerable publishing effort demonstrates the increasing importance of QIM development for new species and products (for example, emerging species in aquaculture) and also of the testing and optimisation of the schemes already published (Gonçalves, Antas, & Nunes, 2007).

The blackspot seabream (*Pagellus bogaraveo*) is common along the continental shelf in the Southern European Atlantic Ocean and throughout the Mediterranean Sea, and has emerged as a potential candidate for European aquaculture (Silva, Andrade, Timóteo, Rocha, & Valente, 2006). From the marketing point of view, blackspot seabream is a species with a high, very stable value all year round, with an increasing demand and consequently higher value and sales just before Christmas (Peleteiro, Olmedo, & Alvarez-Blázquez, 2000).

The QIM is useful essentially because it evaluates sensory parameters and attributes that change most significantly in each fish species during degradation (Erkan & Özden, 2006; Huidobro et al., 2000). The most commonly used attributes for seafood are appearance of eyes, skin and gills, together with odour and texture (Sveinsdóttir, Hyldig, Martinsdóttir, Jorgensen, & Kristbergsson, 2003).

When the linear correlation between Quality Index (QI) and storage time in ice is obtained, the total demerit scores may be used to readily predict the remaining shelf-life (Botta, 1995). Although the QIM is important in predicting the end of shelf-life or rejection time, it should be estimated with the help and support of other evaluation methods.

Although the rejection point in QIM schemes can be estimated by sensory evaluation of the cooked muscle by a panel, for example using the Torry Scale (Martinsdóttir, 1997), this is typical of regions where fish is always commercially presented in fillets. In regions where fish is almost exclusively sold in the whole form, it doesn't make sense the same procedure, as the rejection of the whole fish occurs always sooner than the rejection of the same fish in fillets (by evaluation of external characteristics, as done by consumers when buying), specially those obtained from whole fish stored in ice and filleted in the day of analysis (Barbosa, Bremner & Vaz-Pires, 2002, chap. 11).

On the other hand, the consumption and transportation of seafood products is globally increasing (FAO, 2009) and this increases the need to predict effects of storage and distribution conditions on product shelf-life (Dalgaard, 2000, p. 31). Due to the relatively poor correlation between counts of total numbers of bacteria over storage time, recently models based on enumeration of specific spoilage organisms (SSO) to determine the remaining shelf-life of fish products have been developed (Dalgaard, 2002, chap. 12; Olafsdóttir, Lauzon, Martinsdóttir, & Kristbergsson, 2006).

The dielectric properties of fish skin and muscle are systematically altered during spoilage as tissue components degrade. Measurements of changes in dielectric properties can therefore be used for evaluations of the spoilage degree. Various instruments have been employed to measure physical properties of fish. The Torrymeter (Distell, 2007, p. 87), the RT-Freshmeter (Martinsdóttir, 1987; Vaz-Pires & Barbosa, 2004), and more recently, the TDR reflectometer (Tejada, De las Heras, & Kent, 2007) are among those.

The approach adopted in this study is that the combination of sensory properties and other evaluations like physical parameters or microbial data is much more realistic and precise when whole fish is the product consumers see and buy. The storage quality changes of blackspot seabream in ice were evaluated by using sensory assessment to develop a QIM scheme for this species and using counts of SSO and Torrymeter evaluations to optimise the support of rejection.

2. Material and methods

2.1. Samples

Three experiments were performed between July and September of 2007. Fresh blackspot seabream (*P. bogaraveo* Brunnich, 1768) were purchased at the first auction market in Matosinhos fishing harbour, Porto, Portugal, in three different batches of 12 fish. At the time of purchase, fish were put in ice and immediately transported to the laboratory in polystyrene boxes. Fish were evaluated by the panel on the top of crushed ice, to keep temperature as much as possible close to refrigeration. The samples had an average weight of 281.63 ± 25.98 g, 257.34 ± 38.57 g and 293.33 ± 45.45 g, respectively.

For each batch, 10 fish were randomly chosen for sensory and physical analysis and 2 for microbiological analysis. The fish were kept iced and boxed, in a refrigerator set at 1 ± 1 °C; fresh ice was added daily.

2.2. Development of QIM

To develop the quality index for chilled blackspot seabream, 3 assessors were selected among the staff of the Institute of

Biomedical Sciences Abel Salazar (ICBAS) and Interdisciplinary Centre for Marine and Environmental Research (CIIMAR) on the basis of ability to identify odours and flavours as demonstrated in past training sessions and previous experience with the fundamentals and principles of fish sensory analysis.

The selected assessors evaluated the three batches of ten raw blackspot seabream to design the quality index (QIM). The samples of each batch were presented to the panel in random order. Each member evaluated the ten samples of blackspot seabream in each trial on day 1, 3, 5, 7, 9, 11, 13, 15 and 18. All observations of blackspot seabream were conducted under standardised conditions at room temperature. The first trial was developed to find the characteristics that change clearly with time, necessary to the first draft of the QIM table. The second was used to confirm first trial impressions and clarify points that were less clear. The third was used to final confirmation and simultaneously testing the more consistent parameters found in the previous trials.

The QIM scheme for blackspot seabream lists quality attributes for appearance/texture, eyes, gills, skin, mouth and anal area and descriptions of how they change with storage time. Scores were given for each quality attribute according to descriptions, ranging from 0 to 3. The scores given for all the quality attributes are summarised by the Quality Index, which increases linearly with the storage time in ice.

2.3. Microbiological analysis

Individual areas of 13.9 cm^2 of the skin (two fish from all three trials) were swabbed with sterile cotton swabs. Organisms were transferred to 10 ml of cooled ¼ Ringer solution (Oxoid, Basingstoke, Hampshire, United Kingdom) by vigorous shaking of the swabs. Appropriate series of decimal dilutions were performed, from which surface inoculation was accomplished using the 20 μl drop method in iron agar solid medium (according to Gram, Trolle, & Huss, 1987) and in *Pseudomonas* agar (Oxoid, Basingstoke, Hampshire, United Kingdom). Total viable counts (TVC), as well as selective counts of H_2S-producing bacteria and *Pseudomonas* were performed after two days of incubation at 20 °C. Counts were performed in duplicate and expressed as logarithm of cfu/cm^2.

2.4. Physical evaluation

The Torrymeter 295 (Distell, West Lothian, Scotland, UK) was used for physical evaluation (all 36 fish, from all trials). The measurements were taken in the anterior-dorsal region, first on the right side, then the left. The electrodes, maintained on the top of ice to keep the same temperature (around 0 °C) of the fish (as this, according to manufacturers' instructions (Distell, 2007, p. 87), markedly influences the readings) were cleaned between measurements to remove scales and mucus, and the remaining ice was cleared from the measuring surface. All fish of the three periods were evaluated at 1, 3, 5, 7, 9, 11, 13, 15 and 18 days of ice storage.

2.5. Statistical analysis

Pearson correlation analysis with 95% confidence interval was used to determine the relationships between time of iced storage *versus* QI and time of ice storage *versus* Torrymeter measurements. Additionally, linear regression analysis was accomplished using the statistical software Graph Prism, version 5.01 (Graph Prism Software Inc., San Diego, USA). Linear regression analysis of sensory changes in contrast to time in ice storage and Torrymeter measurements was performed with the data obtained.

Table 2
Scheme of the Quality Index Method (QIM) proposed for whole blackspot sea bream (*Pagellus bogaraveo*).

Quality attribute	Parameter		
Appearance	Dorsal skin	Bright, iridescent, salmon	0
		Slightly bright	1
		Pale, dull	2
	Belly and operculum	Grey, silver	0
		Grey, yellowish spots	1
		Grey, brown spots	2
	Odour	Fresh, seaweedy	0
		Neutral	1
		Sour milky	2
		Metallic	3
Texture	Firmness	Firm	0
		Rather soft	1
		Very soft	2
Mouth	Resistance	Very	0
		Little	1
		Without	2
	Colour	Pinky	0
		Yellowish	1
Anal area	Mucus	Absent	0
		Present	1
	Aspect	Shut	0
		Open	1
		Excessively open	2
Eyes	Cornea	Clear, translucent	0
		Opaque and/or red	1
		Milky, gelatinous	2
	Pupil	Black, bright, shiny	0
		Slightly milky, opaque	1
		Milky, white, opaque	2
	Shape	Plane	0
		Convex	1
		Concave	2
		Deformed	3
Gills	Colour	Bright red	0
		Red, light brown	1
		Brown and/or greenish	2
	Mucus	Absent	0
		Transparent, gelatinous	1
		Milky	2
		Transparent, watery	3
	Odour	Sea weedy	0
		Neutral	1
		Rotten and/or metallic	2
Total QIM score			0-30

The equation that best fit and correlation coefficients (r^2) of QI *versus* storage time in ice and Torrymeter values *versus* storage time in ice were calculated using Microsoft® Excel (Microsoft Co., Redmond, WA, USA).

3. Results and discussion

Initial changes in the following parameters were listed in a preliminary scheme: colour, appearance and odour of skin; texture (elasticity) of flesh; mouth appearance, colour and resistance; bright and colour of anal fluids, shape of the eyes and cornea and pupil appearance and finally colour, mucus and odours of gills. The total demerit points first established was 31. During the development of the scheme, no parameters were found to be useless; the gill odour initial points were modified because rotten and metallic odours occurred simultaneously in a large quantity of fish. Thus, the total of demerit points was defined as being 30.

The first QIM schemes developed by the TFRU were developed as an alternative method of improving both speed and objectives of a grading system and implied to increase the number of criteria (descriptors) and decrease the numbers of grades within each

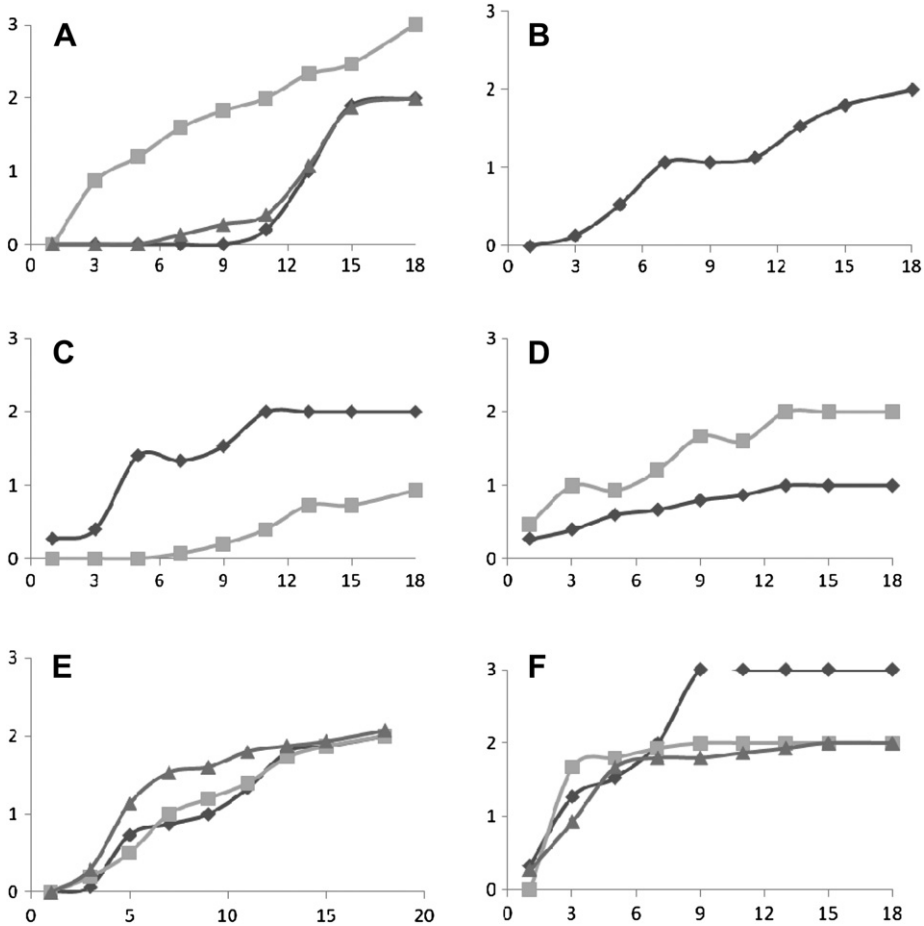

Fig. 1. Average score for each quality attribute: (A) Appearance: ■ dorsal skin, ▲ belly and operculum, ◆ odour; (B) Texture: ■ firmness); (C) Mouth : ◆ resistance, ■ firmness; (D) Anal area: ■ mucus, ◆ aspect); (E) Eyes: ■ cornea, ◆ pupil, ▲ shape); (F) Gills: ■ colour, ◆ mucus, ▲ odour).

criterion (demerit points) (Botta, 1995), but QIM schemes developed more recently are not consensual in relation to which parameters to consider and which to reject, as a result of being species- and product-specifically designed. For the gilthead seabream (*Sparus aurata)*, a fish from the same family which is similar to blackspot seabream in some morphological aspects, five different schemes have emerged. In the first, developed by Huidobro et al. (2000), the QIM has 15 demerit points. Alasalvar, Taylor, Öksüz, Shahidi, and Alexis (2002) described a scheme with 38 demerit points, while Lougovois, Kyranas, and Kyrana (2003) suggested a QIM with 16 demerit points. More recently, Cakli, Kilinc, Dincer & Tolasa (2007) considered again 38 demerit points as the maximum value for QIM of gilthead seabream. Finally, Nunes, Batista, and Cardoso (2007) presented a scheme for gilthead seabream with 20 demerit points.

To develop a QIM scheme for blackspot seabream, the greatest numbers of possible descriptors were chosen. The final scheme suggested in this work includes 30 demerit points, describing six quality attributes with 14 sensory attributes (Table 2).

Fig. 1 shows the results of all parameters considered, during the ice storage.

Odour, as in many previously published fish sensory schemes, appeared to be one of the quality attributes most influenced by ice storage. At the beginning of the storage time, the skin odour was described as fresh or seaweedy and then the odour became neutral. Around the 12 day, the odour was described as sour milky and during the later stages as metallic.

Microbiological analysis of the skin showed that until the 4th day of storage there was no noticeable increase in the numbers of microorganisms (Fig. 2). An initial bacterial flora of around 10^3 cfu/cm^2 remained constant along the first 4 days in ice; this could be expected, as as it corresponds to the lag phase of bacteria growth and changes in this period are mainly attributable to autolytic reactions, enzymatically mediated.

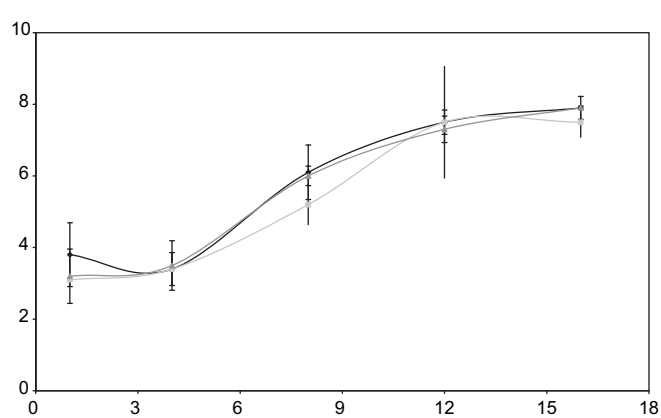

Fig. 2. Bacterial results, shown as total viable count (TVC) (▲), H_2S reducing bacteria (■) and *Pseudomonas* (●), on black spot sea bream stored on ice for 18 days ($n = 6$) CFU = colony forming units.

Table 3
Pearson correlation and linear regression analysis of Quality Index *versus* storage time (QI = *a*. days in ice + *b*).

Experiment	I	II	III	All
Pearson correlation				
r^2	0.967	0.942	0.952	0.957
Linear regression				
Sy.x[a]	0.057	0.076	0.071	0.066
Best fit	$y = 0.051.x+0.124$	$y = 0.051.x+0.125$	$y = 0.052.x+0.084$	$y = 0.051.x+0.114$

Confidence intervals 95%.
[a] Sy.x = standard deviation of residual from line.

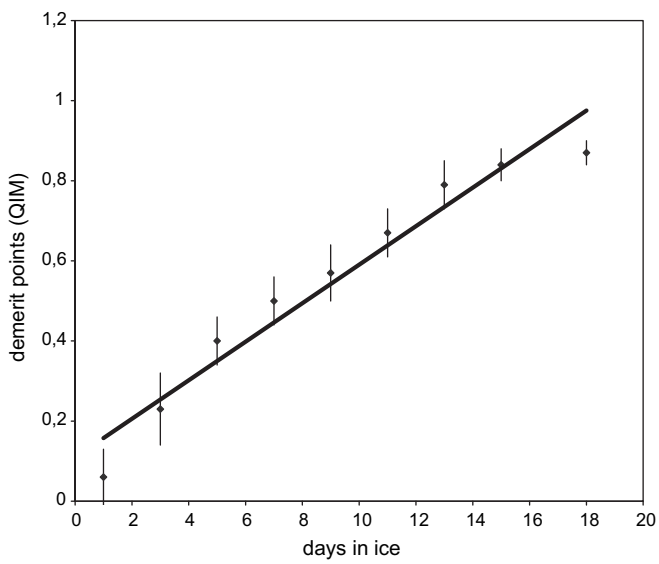

Fig. 3. Quality index of whole raw blackspot seabream during the ice storage at 1.15 ± 0.67 °c (n=3).

After day 4, the bacterial growth became evident (Fig. 2), and on the eighth day there is an increase with values of 10^5 cfu/cm^2 for *Pseudomonas* while for TVC the values were around 10^6 cfu/cm^2. *Pseudomonas* and *Shewanella putrafaciens* have highly specific iron chelating systems (siderophores), but when grown in co-culture on fish samples siderophore producing *Pseudomonas* inhibits *S. putrafaciens* (Gram & Dalgaard, 2002; Olafsdóttir et al., 2006). After day 8, the growth rate of H_2S reducing bacteria is slower, while the growth of *Pseudomonas* increases rapidly (Fig. 2).

Low molecular weight fatty acids are normally associated with sour odours; *Acinobacter* and *Pseudomonas putida* have also been associated with these kinds of odours (Olafsdóttir & Fleurence, 1997; Sveinsdóttir et al., 2003; Whitifield, 2003).

At days 11–12, the gill odour in all fish analysed scored the maximum demerit points, corresponding to intense rotten or metallic odours. *Shewanella putrefaciens* and *Pseudomonas fluorescens* have long been associated with the spoilage of raw fish and its presence is characterised by ammoniacal, spoilt and hydrogen sulphide-type odours (Whitifield, 2003).

Simultaneously, metallic odours in the skin were perceptible, probably due to, among other factors, lipid oxidation, commonly associated with odours at this degradation phase (Ashton, 2002, chap. 14; Undeland & Lingnert, 1999). During the later stages, lipid oxidation occurred, presumptively initiated by the presence of reactive oxygen species generated by autolytic reactions and products of microbiological growth.

Taking into consideration all sensory data, rejection was found to occur on day 12–13 in ice, mainly due to the presence of unpleasant odours in skin and gills.

According to Barbosa, Bremner & Vaz-Pires (2002, chap. 11) the total bacterial count just after catch is variable between 10^1 and 10^4 cfu/g or cm^2 but, at the time of sensorial rejection, it can be as high as 10^6 or 10^7 cfu/g or/cm^2, levels which are in accordance with the counts of microorganisms obtained in the present work.

If we consider the values suggested by these authors as rejection indicators, the results of sensory aspects are confirmed, since on day 12 of ice storage the values from microbiological analyses were 10^6 cfu/cm^2 for H_2S-producing bacteria and 10^7 cfu/cm^2 for *Pseudomonas* and TVC.

Dalgaard (2000, p. 31) reported that different QIM schemes provide different scores at the end of product shelf-life; however, this drawback is reduced by expressing the sensory score in relation to the maximum number of demerit points used for the scheme.

Pearson correlation and linear regression were significant between the QI and storage time, while the three best-fit equations were coincidental (Table 3).

The quality index of whole raw blackspot seabream during ice storage can be seen in Fig. 3.

In Table 4 one can observe that a significant Pearson correlation and a linear regression between the Torrymeter values and the time of ice storage was found in three experiments. The best linear equations for the three experiments are coincident, having the same intercept and slope. Considering all data, the equation as well as the slope and intercept are also coincident with data from the three experiments.

The values of Torrymeter measurements were interpreted as follows: Absolutely fresh fish is given a score of 10; good quality fish receives a score of 6 or more, while scores below 4 indicates fish unfit for consumption (Distell, 2007, p. 87).

Table 4
Pearson correlation and Linear regression analysis of Torrymeter measurements *versus* storage time (QI = *a*. days in ice+ *b*).

Experiment	I	II	III	ll
Pearson correlation				
r^2	0.9516	0.9897	0.9785	0.9829
Linear regression				
Sy.x[a]	0.5402	0.2284	0.3629	0.3815
Best fit	$y = -0.3955x+ 9.305$	$y = -0.3688.x+8.993$	$y = -0.4038.x+9.207$	$y = -0.3894.x+ 9.168$

Confidence intervals 95%.
[a] Sy.x = standard deviation of residual from line.

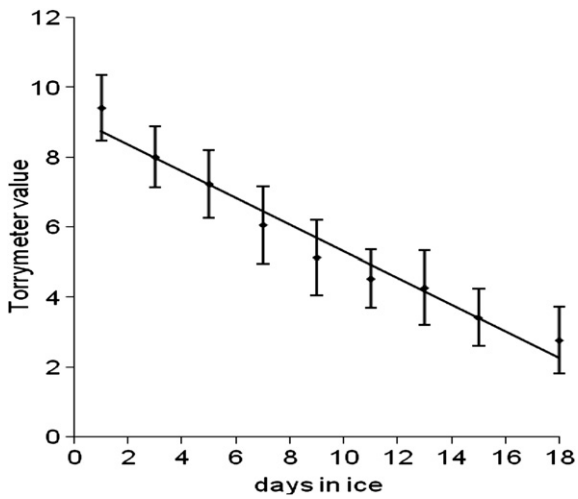

Fig. 4. Torrymeter value of whole raw blackspot seabream during the ice storage.

Table 5
Remaining storage life for blackspot seabream, based on different freshness/spoilage indicators.

Freshness/spoilage indicator	Value at rejection	Rejection day in ice
Quality index	0.66	11
Torrymeter measurements	4.0	13
SSO – *Pseudomonas* log CFU/cm^2	7.5	12
SSO – SPB[a] log CFU/cm^2	6.5	12
SSO – TVC log CFU/cm^2	7.5	12

[a] SPB = Sulphide-producing bacteria.

Torrymeter values of whole raw blackspot seabream during ice storage are shown in Fig. 4.

Considering the value 4 as limit, the moment of rejection occurs at around day 13.

Once the rate of change in the spoilage indicators had been monitored, models were developed in which the measured parameters could be used to predict remaining storage life. Some freshness/quality criteria to predict remaining shelf-life for blackspot seabream are displayed in Table 5.

In conclusion, a shelf-life of 12–13 days was defined for whole raw blackspot seabream stored in ice. The shelf-life was determined by the sensory scores, Torrymeter measurements and microbiological data of SSO. A QIM scheme is proposed in this study; as with other QIM schemes, the future use of this table will probably induce some adaptations and minor changes. Further studies should be undertaken to obtain a comprehension of the chemical degradation of nucleotides and volatile nitrogen compounds and their importance in the freshness/quality indicators in order to confirm the results obtained in the present work.

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