Development of a Quality Index Method to Evaluate Freshness in Mediterranean Hake (Merluccius merluccius)

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ABSTRACT: A Quality Index Method for the sensory assessment of freshness of Mediterranean hake was developed and validated by sensory, chemical, and microbiological parameters. The Quality Index was the ratio between the overall sensory score obtained and the total achievable sensory score of the scheme and ranging 0 (fresh) to 1 (spoiled). This index increased significantly along the time of ice storage, allowing prediction of the remaining shelf life of hake. A value of 0.60 to 0.65 was estimated by statistical treatment as the rejection value, being concordant with sensory score of cooked hake, trimethylamine content, pH, as well as with legal regulations for mesophilic and enterobacteria counts.

Keywords: Quality Index Method, hake, sensory analysis, trimethylamine, ice storage

Introduction

Hake of the genus Merluccius has a worldwide distribution and makes up a considerable proportion of the world catch of fish. The species caught in the Mediterranean sea is the European hake, Merluccius merluccius, which is particularly important for the fishing sector in Spain. In this country, fish is usually stored in boxes with ice during transport and commercialization.

Characteristic sensory changes occur in the appearance, odor, taste, and texture of fish during deterioration, and thus, sensory methods are commonly used for quality assessment by inspection services and in the fishing industry. Sensory analysis has the advantage of being rapid and simple. However, it shows a certain degree of subjectivity, which is only partially avoided by using an expert and extensively trained panel. Over the last 50 years a large number of sensory schemes have been developed for sensory analysis of raw fish. In Europe, the most commonly accepted method is the EU scheme, introduced in 1976 and updated in 1996 (EEC 1996). This method includes 4 descriptive levels and grades the freshness of fish from E (extra), A (acceptable), and B (poor) to C (unacceptable for human consumption). This method is widely used for a variety of fish and has been satisfactorily correlated with chemical parameters, such as volatile amines (Pérez-Villarreal and Howgate 1987), microbial counts (Pastoriza and others 1998), and time of ice storage (Koutsoumanis and Nychas 1999). However, its suitability has been questioned because, in using general parameters, it does not take into account particular differences among species.

Alternative and more specific sensory methods, such as the so-called Quality Index Method (QIM), have been developed for various species of raw fish. The QIM is based on detailed descriptors that are grouped into distinct characters within general attributes, such as general appearance, eyes, and gills. Unlike the traditional systems, the QIM descriptors should be precise, objective, independent, and primary rather than a cluster of terms (Luten and Martin-sdotit 1997).

The QIM has been recognized as a fast and reliable approach to assess the freshness of fish (Botta 1995). The usefulness of this tool will be further improved when new schemes applicable for particular fish species or products are developed (Dalgaard 2000). In fact, specific QIMs have been already designed for species such as cod (Larsen and others 1992; Warm and others 1998), sea bream (Huidobro and others 2000), and others (Botta 1995). Moreover, a QIM software (available on the “QIM Eurofish” Web site at http://www.qim-eurofish.com) has been developed for anchovy, brill, cod (fresh and frozen), haddock, flounder, herring, hoki, plaice, redfish, saithe, salmon, sardines, sole, spotted trevalla, turbot, whiting, and 4 species of warm water fish from Australia (Dalgaard 2000). However, despite limitations in the current European system (Simeonidou and others 1998; Dalgaard 2000), to date no QIM has been described particularly for Mediterranean hake. Neither is the traditional Torry scheme for lean fish appropriate to grade Mediterranean hake, since it is inconsistent with the results of both chemical and sensorial tests (Baixas-Nogueras and others 2002).

In the framework of the European project CT3253, the aim of this work was to describe a QIM for the sensory assessment of raw Mediterranean hake. To develop and validate the proposed QIM, sensory, chemical (volatile amines and pH), and microbiological (total counts of mesophilic bacteria and enterobacteria) changes were monitored during ice storage. Chemical and microbiological parameters were used, together with complementary sensory analysis of cooked fish, to establish a sensory Quality Index (QI) value as a limit of hake acceptability for human consumption.

Material and Methods

Samples

Three treatments were performed in May (Treatment 1), July (Treatment 2), and December (Treatment 3) of the same year. Fresh and gutted hake (Merluccius merluccius var. mediterraneus) were purchased from the local Barcelona market and immediately transported in ice to the laboratory. The samples had been caught the night before. To reduce variability factors that could hinder the interpretation of results, similar sized fish were chosen. Individuals had an average weight of approximately 350 g and average length of 35 to 40 cm, which correspond to the most usual size found in the local markets. They were stored in flaked ice (0 °C) in self-draining...
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boxes and inside a refrigerator set at 4 °C. Boxes were drained and melted ice was replaced daily. Sensory assessment of raw samples with the QIM was performed on d 0, 2, 6, 8, 10, 12, and 14, while chemical and microbiological measurements and complementary sensory analysis were carried out on d 0, 8, 10, and 14 of storage. All measurements were done at least in duplicate.

Sensory analysis

Panelists (8 members), males and females from 25 to 40 years old, were from the staff of the Dept. of Nutrition and Food Science, Univ. of Barcelona. They were used in sensory analysis although an additional training was performed to familiarize them with the sensory scheme for hake freshness evaluation (Table 1). Several training sessions using fresh and stale samples were organized in order to get a fairly uniformity degree of sensory evaluation.

Proposed QIM for raw hake. To develop the QIM, preliminary sensory studies were carried out to establish the most significant criteria associated with hake spoilage during storage in ice. The general EU grading scheme (Howgate and others 1992) was taken into account for the description of each attribute, although in the QIM the freshness of hake was not based on an average of distinct groups of characteristics. Each single descriptor has an associated demerit point ranging from 0 to a maximum value of 3 to 4. Characters with less importance were given lower scores (Nielsen 1997), while the maximum of 4 prevented a single character from excessively unbalancing the overall assessment. The scores for all characters are considered together, as the sum, to give an overall sensory score. The lower the score, the greater the freshness of the fish.

Cooked hake. The sensory Assessment Score Sheet for Cooked White Fish was used following the Torry scheme (Anonymous 1989). In this method odor, flavor and texture, and appearance of cooked hake were evaluated using a scale from 10 (very fresh fish) to 3 (spoiled fish). Random portions of samples were cooked in a microwave (500 W, 3 min) in a receptacle covered with a perforated plastic film, and were then immediately presented to the panelists. Frozen hake samples (kept at –18 °C from just after acquisition) were used as controls in each sampling point.

Chemical analyses

Trimethylamine and total volatile basic nitrogen determination. Analyses were made applying a Flow Injection/Gas Diffusion method (FJGD) following Baixas-Nogueras and others (2001). This procedure is based on the colorimetric detection of basic volatile compounds, volatilized from a 7.5% trichloroacetic acid extract after alkalization of the injected solution.

pH. The pH was measured directly from samples using a pH meter (Model 2001, Crison, Spain), by inserting a Xerolyt electrode (Crison, Spain) into a mixture of fish and distilled water (1:1).

Microbial analysis

Total counts of mesophilic bacteria were done on Plate Count Agar incubated at 32 °C for 72 h, and enterobacteria were counted on Violet Red Bile Glucose Agar incubated with a double layer at 37 °C for 24 h (Pascual-Anderson 2000).

Statistical analysis

The statistical software SPSS 10.0 for Windows (SPSS Inc., Chicago, Ill., U.S.A.) was used to analyse data. The non-parametric test was applied when data were not normally distributed (Shapiro Wilk test significant) (Doménech-Massons 2000a). Linear regression analysis of sensory changes in contrast to time of ice storage was done with the data obtained. The Kruscal Wallis test (Doménech-Massons 2000b) was used to establish the significance of the differences of QI values among treatments. A Receiver Operating Characteristic (ROC) curve (DeLong and others 1988) was applied to evaluate the suitability of the QIM (from the value of the area under the curve, AUC), and the accuracy of a limit of acceptability (from the sensitivity and specificity values). Concordance of the rejection point obtained according to chemical, microbiological, and sensory parameters was tested by Kappa indexes (Doménech-Massons 2000c).

Results and Discussion

The QIM DEVELOPED TO ASSESS HAKE DURING STORAGE IS A NON-DESTRUCTIVE procedure since it takes into account only external attributes. It has a total maximum score of 6 for general appearance (skin and tissue softness) and gills, and 7 for eyes (Table 1). Each descriptor within a character was adjusted according to the freshness/spoilage changes observed during ice storage. Common words were used for the descriptors to facilitate comprehension, which is consistent with the recommendations of other study about the importance of the descriptive vocabulary used (Bárcenas and others 2000). The scores for each descriptor were grouped to give an overall sensory score (SS) with a maximum of 19. No descriptor dominated the system, and, thus, small differences in the score of a particular descriptor did not unbalance the overall value. For each sensory attribute, the scores increased progressively during storage in all 3 treatments (Figure 1) and showed good correlation \( (p < 0.001) \) with storage time, both in individual treatments and in all 3 treatments considered together. The global correlation coefficients were 0.907 for general appearance, 0.916 for eyes, and 0.928 for gills.

As Dalgaard (2000) pointed out, different schemes provide dis-
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tinct scores that correspond to the end of product shelf life; therefore, it is difficult to locate an overall score for a specific state of freshness. This drawback is reduced by expressing the sensory score in relation to the maximum number of demerit points used for the scheme.

In our case, the scoring system, Quality index (QI), was calculated as the following ratio:

\[
\text{QI} = \frac{\text{SS}}{19}
\]

where SS means the overall Sensory Score resulting from the sum of the scores of each character assessed, and 19 is the maximum achievable score for the proposed QIM. Thus, raw hake QI ranged from 0 (excellent quality) to 1.

The profile observed for the QI of raw hake throughout storage was comparable \((p > 0.05)\) among treatments (Figure 2). Therefore, the season in which fish were caught did not affect spoilage process. Initial QI values (time zero) for raw hake were 0 in all 3 treatments, which indicates excellent quality. The QI then increased gradually and significantly \((p < 0.05)\) until an average of 0.85 (standard deviation, SD = 0.03) after 14 d of ice storage. Good correlation was observed between QI and time of storage in each treatment as well as all 3 treatments considered together, \(r = 0.957\) \((p < 0.001)\) being the global correlation coefficient.

There are legal regulations for total mesophilic microbial counts and total volatile basic nitrogen (TVB-N), which allows assessing fish freshness. Limits for acceptability or rejection points have been set by the European Union. Total counts of mesophilic bacteria showed an initial average of 3.33 log cfu/g (SD = 0.45) and exceeded the legal limit of 6 log cfu/g (MSC 1991) between d 8 and 10. TVB-N did not increase in the 1st 10 d of storage, but only on d 14. At this point, TVB-N values were almost 30 mg/100 g, which is close to the limit of acceptability (30 to 35 mg/100 g) established by the European Union regulation (EEC 1995). When the ROC curve was applied against mesophilic and TVB-N measurements in the sensory analysis, the AUC was always higher than 0.930, which supports the usefulness of the test (Swets 1988). Moreover, the QI range of 0.60 to 0.65 (corresponding to 8 to 10 d of ice storage) was the most accurate indicator of acceptability, since in all cases the values of sensitivity and specificity were over 0.75 (Burgueño and others 1995).

Sensory analysis of cooked samples as well as other chemical and microbiological parameters were also examined to check whether they supported the suitability of the QIM proposed (Table 2).

Odor, taste, and texture-appearance in cooked hake decreased gradually with time of storage \((r = 0.97; p < 0.001)\) in all 3 treat-
ments. The limit of 3 proposed by Torry (Anonymous 1989) would imply the acceptability of hake even after 14 d of storage, which was found to be not exigent enough for rejection (Baixas-Nogueras and other 2002). In this regard, Einarrson (1999) proposed an average Torry grade of 3.5 as a more adequate limit of acceptability for cooked lean fish. Therefore in our study, hake would be rejected around d 10 of ice storage, which is consistent with the other parameters.

Trimethylamine (TMA-N) showed initial levels lower than 1 mg/100 g, indicating an excellent quality grade according to the classic Castell criterion (Castell and others 1958). TMA-N increased through storage, reaching over 10 mg/100g. Assuming 5 mg/100g as a limit of acceptability for hake (Burgess 1979), our samples were acceptable until d 8 of ice storage. Therefore, 10 d of storage would also be the shelf life according to this chemical index.

Initial pH values increased progressively and significantly (p < 0.05) throughout the 3 treatments, mainly because of the production of basic compounds by bacterial growth. Moral (1987) proposed pH 7 as a limit of acceptability for fresh hake, and in our study this value was surpassed just after 10 d of ice storage.

Enterobacteria were counted only in 2 treatments and showed low values in initial fresh samples, which increased with storage, exceeding the legal limit of 3 log CFU/g (MSC 1991) after 8 to 10 d.

Satisfactory statistical correlations were obtained between complementary sensory score of cooked hake, chemical and microbiological parameters, and the QI (Table 3). Only in the case of TVB-N was the correlation less satisfactory.

In addition, statistical Kappa indexes (Doménech-Massons 2000c) were applied to study the concordance of rejection point between sensory, chemical, and microbiological parameters with the QI, all of which are recognized procedures to assess fish quality. Taking into account the limits mentioned along the paper for each studied parameter, Table 3 shows the Kappa indexes obtained together with the corresponding concordance levels with the QI. Only in the cases of TVB-N and cooked hake with a sensory score limit of 3 was concordance unsatisfactory, which is in agreement with the limitations of TVB-N as a freshness index and the inadequate exigency of the Torry limit.

As stipulated by law (MSC 1992), chemical and microbiological determinations must be performed if any doubt arises with the sensory analysis. In this regard, Anastasio and others (1999) reported that a combination of chemical and sensory methods would be the most suitable way to evaluate the freshness/spoilage of fish. Our results indicate that, among the chemical parameters, TMA-N is the most appropriate to complement the QI, since TMA-N evolution shows the best correlation with sensory changes of raw hake. Moreover, according to Kappa indexes the limit of acceptability of TMA-N and QI parameters is strongly concordant.

Conclusions

The QIM is a simple but reliable tool to assess the freshness of Mediterranean hake during storage in ice. The QI range of 0.60 to 0.65 seems an optimal range of acceptability for this fish in this storage media, since it is consistent with other legal or proposed limits for sensory scores in cooked fish, and chemical and microbiological parameters. Moreover, the QIM had an added value derived from the linear relationship between the QI and the time of storage, since it can be used to establish the remaining shelf life from the information obtained with freshness QI.

References


Table 2—Results of the chemical and microbiological parameters during ice storage of Mediterranean hake (Merluccius merluccius)

<table>
<thead>
<tr>
<th>Day</th>
<th>Mesophilic bacteria (log CFU/g)</th>
<th>Enterobacteria (log CFU/g)</th>
<th>TVB-N (mg/100g)</th>
<th>TMA-N (mg/100g)</th>
<th>SS cooked hake pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Treatment 1 2.90 – 1 14.54 0.08 6.76 9.60</td>
<td>Treatment 2 3.28 – 2 15.29 0.33 6.84 9.33</td>
<td>Treatment 3 3.80 nd2 12.91 0.35 6.72 9.80</td>
<td>Mean 3.33 0.45 14.25 0.25 6.77 9.78</td>
<td>SD2 0.45 0.63 1.22 0.25 0.16 0.17</td>
</tr>
<tr>
<td>8</td>
<td>Treatment 1 5.23 – 2 10.54 0.57 6.79 9.70</td>
<td>Treatment 2 5.88 – 2 15.33 0.34 6.63 9.48</td>
<td>Treatment 3 6.50 3.23 14.05 2.51 6.69 6.24</td>
<td>Mean 5.24 3.10 12.71 2.68 6.83 6.54</td>
<td>SD 0.36 0.18 1.89 1.21 0.19 1.24</td>
</tr>
<tr>
<td>10</td>
<td>Treatment 1 6.67 – 2 12.09 3.40 7.04 6.63</td>
<td>Treatment 2 5.33 3.23 13.16 6.44 6.99 5.06</td>
<td>Treatment 3 6.22 3.45 19.59 7.39 6.93 5.06</td>
<td>Mean 6.07 3.34 14.95 5.74 6.99 5.58</td>
<td>SD 0.68 0.15 4.06 2.08 0.95 0.91</td>
</tr>
<tr>
<td>14</td>
<td>Treatment 1 7.26 – 2 29.06 12.26 7.08 4.04</td>
<td>Treatment 2 6.80 3.90 32.07 10.72 7.25 3.61</td>
<td>Treatment 3 6.72 3.93 30.73 11.81 7.31 4.24</td>
<td>Mean 6.93 3.92 30.62 11.33 7.21 3.96</td>
<td>SD 0.29 0.02 1.51 0.85 0.12 0.32</td>
</tr>
</tbody>
</table>

1not determined 2not detected 3Standard deviation

Table 3—Correlation and Kappa indexes between Quality index (QI) and the complementary cooked sensory, chemical, and microbiological parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Legal or suggested rejection value (reference)</th>
<th>Correlation coefficient (r)</th>
<th>Kappa index</th>
<th>Concordance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooked sensory</td>
<td>SS2 = 3 (1) SS = 5.5 (2)</td>
<td>0.957***d 0.67-0.77</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>TMA-N 5 mg/100g</td>
<td>0.818*** 0.77-0.88</td>
<td>Good-Very good</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVB-N 30-35 mg/100g</td>
<td>0.609** 0.28-0.33</td>
<td>Weak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH pH = 7</td>
<td>0.821*** 0.65-0.67</td>
<td>Good</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesophilic bacteria 6 log CFU/g Enterobacteria 3 log CFU/g</td>
<td>0.891*** 0.89-1.00</td>
<td>Very good</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.925*** 0.66-0.68</td>
<td>Good</td>
<td></td>
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</table>

References


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