Differences in chemical, physical and sensory properties during shelf life assessment of wild and farmed gilthead sea bream (*Sparus aurata*, L.)

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Summary

The aim of this study was to determine and compare differences in physical, chemical and sensory post-mortem changes between wild (*W*) and farmed (*F*) gilthead sea bream (*Sparus aurata*). Ungutted fish were stored in ice from harvesting up to 20 days and freshness indicators were analyzed at regular intervals. Proximate composition of the samples differed in lipid (*W* = 0.86 ± 0.12; *F* = 4.18 ± 0.16) and moisture content (*W* = 79.12 ± 0.48; *F* = 74.50 ± 0.82). Data from sensory evaluation were described using linear regression models. Sensory schemes for cooked and raw fish were found to be suitable in establishing specific attribute deterioration and shelf life duration (*W* = 14 days; *F* = 17 days). Changes in pH and dielectric properties were influenced by changes in lipid content, while changes in total volatile base nitrogen and trimethylamine showed high correlation with sensory assessment and storage time, but stayed below the acceptance limit for human consumption (*W* = 24.47 mg TVB-N/100 g and 4.14 mg TMA-N/100 g; *F* = 26.18 mg TVB-N/100 g and 3.84 mg TMA-N/100 g), and thus were not reliable indicators of quality changes during storage in ice. Deterioration of flesh lipids, assessed by thiobarbituric acid index, differed between the samples, but presented no serious problem during storage time. In order to determine the importance of individual results, all obtained data were submitted to principal component analysis. Variations in sensory, physical and chemical assessment were described by PC1 (storage time); variations in lipid and moisture content were described by PC2 (capture grounds). A clear separation of the investigated samples, according to the storage time and capture grounds, was observed.

Introduction

Freshness and spoilage are the most important criteria to determine the overall quality of food products. Considerable effort has been invested in the search for suitable methods to assess freshness while the product is still edible by setting quantitative standards on spoilage processes (Sykes et al., 2009). Factors such as feed access and composition, as well as environmental history differences, affect sensory attributes and quality of wild and farmed fish. As one of the main species farmed in Mediterranean countries, the demand for fresh gilthead sea bream has increased significantly over the past decade; the investigation of quality changes during storage continues to be of major interest to industries, retailers and consumers; however, most studies have been conducted on farmed sea bream (Alasalvar et al., 2001; Cakli et al., 2007; Özogul et al., 2007). Although limited, the literature indicates significant differences in organoleptic characteristics of wild and farmed samples of the same species. Farmed specimens have a softer texture and less robust flavour, thus consumers prefer farmed fish from the wild (Alasalvar et al., 2002; Grigorakis et al., 2003). Of interest is to compare other quality indicators, such as volatile amines, dielectric properties or deterioration of flesh lipids during ice storage.

Sensory evaluation is the most commonly used method for quality assessment of raw fish; the Quality Index Method (QIM) has been suggested as being a precise, objective, non-destructive, rapid, simple to apply and species-specific sensory method for an independent description of outer appearance attributes of raw fish using a scoring system of 0–3 demerit index points for each characteristic (Olafsdottir et al., 1997; Huidobro et al., 2000; Martinsdottir et al., 2009). The total sum of all points gives an overall sensory score, a so-called quality index (QI). Freshness parameters such as texture, odour and flavour are used in the Torry freshness scoring to determine the sensory response of cooked fish samples (Martinsdottir et al., 2001). Post-mortem quality changes in fish vary with season, species, fishing method, handling, and holding temperature; therefore physical and chemical muscle changes should be correlated with sensory assessment results (Huss, 1988; Sikorski et al., 1990; Olafsdottir et al., 1997). The post-mortem muscle content of volatile amines provides information on the progression of spoilage and is suitable for confirming sensory data (Venugopal, 2002), while changes in dielectric properties of fish skin are closely related to spoilage rates.

The objective of this study was to identify specific post-mortem changes and shelf life of two fisheries products of the same commercially important species: wild and farmed gilthead sea bream. To achieve this we determined and compared their physical, chemical and sensory changes while preserving the fish on ice.

Materials and methods

Sampling of the fish and storage conditions

A total of 400 commercial-sized fish (380–420 g) were used in the study: 200 farmed gilthead sea bream (*Sparus aurata*) were obtained directly from the local farm (*F*) and 200 fish were caught by fishermen in the coastal part of the Central Adriatic (*W*). Samples were taken in April 2010. Fish were killed by immersion in ice-cold water and placed in self-draining polystyrene boxes, packed in flaked ice and delivered to the laboratory within 3–4 h of harvesting. Temperature of the fish
upon arrival was 2 ± 1°C. First samples for chemical and sensory analysis were taken on the same day, while the remainder of the fish were repacked for 20 days in cold storage at 0 ± 2°C. Fresh ice was added daily in a 2 : 1 fish-to-ice ratio. To avoid direct contact of ice with the fish skin, very thin plastic sheeting was used to cover the fish.

**Proximate composition analysis**

Proximate composition analyses of wild and farmed gilthead sea bream were conducted upon arrival of the fish (day 0). Randomly chosen fish (four wild and four farmed) were filleted (with skin on) and homogenized in a cutting mill (GM 200; GRINDOMIX, Retsch, Germany). The homogenates were used for all chemical analyses. Moisture, protein, total lipid and ash content were determined according to AOAC (2000) procedures. All analyses were done in triplicate for each fish.

**Sensory evaluation of cooked and raw fish**

During the shelf life study, six trained and experienced sensory panel members made sensory evaluations of the cooked fillets and raw fish. Maximum storage shelf life of wild and farmed gilthead sea bream was determined by sensory evaluation of 16 (eight wild and eight farmed) cooked samples, using a Torry scheme adapted to raw gilthead sea bream using a descriptive scale from 0 to ±3, with 10 being absolutely fresh fish and ±3 being completely putrid or spoiled fish (Alasalvar et al., 2001).

The dorsal halves of the fish fillets were placed in a plastic bag with water added, then sealed and heated in a microwave oven (600 W) for 3 min. After 5 min the fillets were served to panelists and assessed for odour, flavour and texture. An average score (0–15) for gilthead sea bream earlier described by Huidobro et al. (2000). The QIM scheme consists of eight parameters, examined on days 0, 7 and 15 of ice storage. The pH was measured using a digital pH meter (Iska pH-Meter MA 5705, Slovenia) equipped with a glass electrode, calibrated at four standard deviation. Differences between wild and farmed samples were determined by direct distillation of fish extracts as previously described in Šimat et al. (2009a) and expressed as mg TVB-N/100 g fish muscle (mg per kg).

**Total volatile base nitrogen (TVB-N)** and trimethylamine nitrogen (TMA-N) content of wild and farmed gilthead sea bream samples were determined by direct distillation of fish extracts as previously described in Šimat et al. (2009a) and expressed as mg TVB-N/TMA-N/100 g fish muscle (mg per 100g).

**Statistical analyses**

Results of repeated analyses were reported as average ± standard deviation. Differences between wild and farmed samples were analysed statistically by Student’s t-test. For comparison of means, one-way analysis of variance (ANOVA) followed by Fisher’s least significant difference (LSD) test at the 95% confidence level was used. Data from sensory evaluation (cooked and raw fish) and Torrymeter measurements were described using linear regression models and the equations for regression lines calculated from all individual data. Pearson’s correlation coefficients were used to determine the relation between the physical and chemical measurements to sensory panel results. The principal component analysis (PCA) was used to determine the importance of individual parameters and the relationship among them. Prior to PCA the variables were standardized to a mean of zero and variance of one.

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**Table 1**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Attributes</th>
<th>Demerit points</th>
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<tbody>
<tr>
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<td>Skin</td>
<td>Very bright</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bright</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blurred, faded</td>
</tr>
<tr>
<td></td>
<td>Slime</td>
<td>Clear-transparent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slightly cloudy/cloudy</td>
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<tr>
<td>Flesh</td>
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<td>Elastic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marked by pressure</td>
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<td>Strongly fishy</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Off odours</td>
<td>3</td>
</tr>
<tr>
<td>Gills</td>
<td>Colour</td>
<td>Bright/dark red</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brownish red/discoloured</td>
</tr>
<tr>
<td></td>
<td>Odour</td>
<td>Fresh/seaweed</td>
</tr>
<tr>
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<td>Neutral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fishy</td>
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<tr>
<td></td>
<td></td>
<td>Off odours</td>
</tr>
<tr>
<td>Quality index (QI)</td>
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</tr>
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</table>

**Physical and chemical analysis**

The pH value, thiobarbituric acid index, and volatile amines (TVB-N and TMA-N) of both wild and farmed samples were investigated on days 0, 7 and 15 of ice storage. The pH was measured using a digital pH meter (Iska pH-Meter MA 5705, Slovenia) equipped with a glass electrode, calibrated at four and seven. The electrode was dipped into the fish and distilled water (1 : 1) mixture at ambient temperature (Kyran and Lougouvios, 2002).

Changes in the dielectric properties of both wild and farmed samples were determined using the GR Torrymeter (Distell Industries Ltd., Scotland, UK) over 20 days. A single measurement was obtained from each of the 16 (eight wild and eight farmed) fish by applying the meter probe above and parallel to the lateral line, just behind the gill cover. Instrument readings were read on a digital display, with 17 being the highest value and zero the lowest.

Thiobarbituric acid index (TBA) was determined in trichloroacetic acid-fish extracts as previously described by Vyncke (1970) and Lemon (1975), using a spectrophotometer (PRIM Advanced, Secomam, France). Results were expressed as mg malondialdehyde/kg muscle (mg MA per kg).

Total volatile base nitrogen (TVB-N) and trimethylamine nitrogen (TMA-N) content of wild and farmed gilthead sea bream samples were determined by direct distillation of fish extracts as previously described in Šimat et al. (2009a) and expressed as mg TVB-N/TMA-N/100 g fish muscle (mg per 100g).
statistical analyses were performed using the Statistica 8 (StatSoft Inc., Tulsa, OK, USA) software package.

Results

Proximate analysis of wild and farmed gilthead sea bream

Proximate composition analyses of wild and farmed gilthead sea bream are shown in Table 2. As expected, significantly higher lipid content and correspondingly lower moisture content were found in farmed samples. A statistically significant difference was observed between the means of moisture and lipid content, but not between crude protein and ash content of wild and farmed gilthead sea bream. Additional lipid analyses, taken on days 7 and 15 of ice storage, showed no significant differences in lipid content at the different stages of storage. Average lipid content during the entire storage time was 0.92 ± 0.14% for wild and 4.29 ± 0.16% for farmed samples.

Sensory assessment

Results from the sensory evaluation of cooked fillets from raw wild and farmed gilthead sea bream are shown in Fig. 1. Sensory quality of both wild and farmed fish decreased with storage time. A statistically significant difference (P < 0.05) was observed between the means of Torry scores (odour, flavour and texture) of wild and farmed fish. Wild samples received lower scores throughout the storage, especially after day 11 when boiled dish cloth odour, intensive sour off-flavour, flakiness of the fillet and dry and fibrous texture developed. After 14 days in ice the farmed samples were characterized by a boiled potato or cheesy/sour milk odour, slightly off umami-like flavour and a rubber but fibrous texture. Colour was not taken into the calculation of the Torry score, but panelists were asked to observe and comment on the colour of cooked fillets. Five panelists found the greyish colour of wild samples fillets less appealing. The higher lipid content did not seem to contribute significantly to the development of rancidity. Only two panelists reported a slightly rancid flavour in cooked farmed fish samples at the end of storage. Shelf lives of farmed and wild samples were calculated from the regression line equations, taking a score of 5.5 as the rejection point, and were found to be 17 and 14 days, respectively (Fig. 1).

Sensory attributes were described by means of the quality index score (QI) over storage time on ice (Fig. 2). QI score increases evolved linearly, showing high positive correlation with storage time for both wild (r = 0.989, P < 0.01) and farmed (r = 0.968, P < 0.01) samples. Farmed samples received lower QI scores throughout storage. Main differences between the two fish groups were in skin appearance, flesh firmness, odour and gill colour. During storage of farmed samples the general fading of colours, with yellowish slime on the skin, slow loss of flesh firmness and evolution of milky mucus on gills were observed. In wild fish a blurred greyish colour, rapid loss of firmness and scales, and brown-clotted mucus on the gills developed with increased storage time. Maximum QI score was reached on day 14 for wild and day 17 for farmed samples. These results suggest that the QIM scheme was suitable for freshness assessment of both wild and farmed raw gilthead sea bream stored on ice.

Physical and chemical analysis

Levels of pH, TBA (mg MA per kg), TVB-N (mg per 100 g) and TMA-N (mg per 100 g) at three different stages of ice storage for wild and farmed gilthead sea bream are shown in Table 3. First pH measurements of the samples were taken 6 h after death, thus low initial pH could be a result of muscle glycogen being metabolized into lactic acid. The pH of the muscle increased during storage in both wild and farmed fish samples. Fish were similar in size thus the statistically significant difference (P < 0.05) observed between the samples could result from different feed (not analysed in the study) or harvesting methods. At the end of storage the pH values of both groups grew to levels that indicate the production of some alkaline metabolites correlated with spoilage.

![Fig. 1. Changes in cooked sensory scores (Torry score), wild and farmed gilthead sea bream samples against storage time on ice. Each point = mean of eight fish; vertical bars = standard deviation](image)

![Fig. 2. Changes in QI scores, wild and farmed gilthead sea bream samples against storage time on ice. Each point = mean of eight fish; vertical bars = standard deviation](image)

![Table 2](image)

Table 2: Proximate analysis (means ± standard deviation; n = 12; % on wet weight basis), wild and farmed gilthead sea bream

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture (%)</th>
<th>Protein (%)</th>
<th>Lipid (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild</td>
<td>79.12 ± 0.48*</td>
<td>19.87 ± 0.36*</td>
<td>0.86 ± 0.12*</td>
<td>1.12 ± 0.06*</td>
</tr>
<tr>
<td>Farmed</td>
<td>74.50 ± 0.82*</td>
<td>19.55 ± 0.30*</td>
<td>4.18 ± 0.16*</td>
<td>1.05 ± 0.03*</td>
</tr>
</tbody>
</table>

a–bMeans in the same column and with same letter do not differ significantly, P < 0.05.
Changes in dielectric properties between wild and farmed gilthead sea bream showed statistically significant differences (P < 0.05) during storage (Fig. 3). Due to their higher lipid content, farmed samples showed faster decline in Torrymeter readings throughout the storage and a higher variability between individual readings, especially after day 11 of storage. Values determined at the end of shelf life suggested that the range of Torrymeter readings was different between wild and farmed gilthead sea bream samples (Table 3). The increase of TVB-N levels with storage time was small, <10 mg per 100 g over 15 days. Despite the initial levels close to the limit established for freshly caught fish (20 mg per 100 g), values at the end of storage remained below the recommended limit for acceptability of 30–35 mg TVB-N/100 g. Similar results were obtained for TMA-N analysis (Table 3), and levels found after 15 days of storage were <5 mg per 100 g. At the sensory rejection point of the samples (F = 17 days, W = 14 days), the content of volatile amines did not indicate spoiled fish, thus these should not be taken as reliable indicators of freshness for wild and farmed gilthead sea bream.

The qualitative characteristics of studied parameters described by PCA are shown in Fig. 4. Distinct separation of wild and farmed samples was observed, placing the two sets of data opposite to each other and separating them according to the storage time and catching grounds (Fig. 4a). The proportion of variance accounted for by the first two principal components (PC1 and PC2) was 93.32%, while the remaining PCs each accounted for less than 3% of the total variance. High correlations were observed among all parameters studied. The most important parameters were quality index (0.941) and Torry scores (0.966), while the remainder of the studied parameters showed correlations >0.877 (Fig. 4b). Parameters with the highest variable contributions (between 0.13 and 0.16) to PC1 were storage time, sensory assessment (QI and Torry scores), TVB-N and pH value. The lipid content of the fish had the highest contribution (0.74) to PC2.

Discussion

The chemical composition varies greatly between species and individuals of the same species, mostly due to age, sex, migration, environment and seasonal variations (Hyldig et al., 2007), but also due to feed composition and activity of the fish (Alasalvar et al., 2002). Using the 5% total lipid level as a cut-off point between low and medium fat fish (Ashton, 2002), the muscle lipid content defines both fish groups analysed in this study as low fat fish. Total body lipids are known to increase with size, and in all cases wild fish were found to have much lower lipid content than their farmed counterparts (Grigorakis et al., 2002). The protein content is considered a stable component in fish proximate composition, with some changes related to fish weight. Fish analysed in this study had similar weights, thus the protein and ash content of the samples did not differ significantly. Previous studies also reported similar proximate composition of wild and farmed gilthead sea bream (Kyrana et al., 1997; Alasalvar et al., 2002; Grigorakis et al., 2003).
Differences in sensory assessment of farmed and wild gilthead sea bream were observed in both the cooked and raw sensory scores. The evolution of spoilage given as the sum of demerit points was more pronounced in wild samples. Farmed fish had a less intensively fishy taste, but were milkier and whiter in appearance, which could be related to higher water content. Grigorakis et al. (2003) found wild gilthead sea bream to have greater acceptance than farmed fish and that this preference seemed to be related to taste and flavour of the fish rather than to textural properties; however, they found much higher lipid contents compared to samples analysed in our study. Alasalvar et al. (2002) found no difference over time between sensory scores of cooked farmed and wild sea bream. These differences can be explained by the fact that cooking the fish may mask or remove undesirable changes observed, providing these changes are not extreme. With firmer texture and milder odours and lower demerit points of eight quality parameters, the farmed fish in our study resulted in better acceptance and longer shelf-life compared to wild samples. The storage life of farmed gilthead sea bream determined in other studies was similar to our results and ranged between 9–20 days depending on the packing method (Kyrana et al., 1997; Huidobro et al., 2000; Alasalvar et al., 2001; Lougovois et al., 2003; Chouliara et al., 2004; Özogul et al., 2007). The maximum shelf life of wild gilthead sea bream determined by sensory evaluation was not previously reported in the literature; however, Alasalvar et al. (2002) found the limit of acceptability of wild gilthead sea bream to be 16–18 days based on concentration of ATP breakdown compounds during ice storage.

Typical pH of the live fish is around seven, thus the initial low pH of the samples could reflect good quality and freshness of the fish or that fish underwent some stress before capture (Kristoffersen et al., 2006). Tejada and Huidobro (2002) reported rapid decrease from 7.2 to 6.4 in the initial pH of gilthead sea bream muscle in the first 5 h after death, and the increase in muscle pH to 6.8 during storage regardless of the slaughter method. In a shelf-life study of ice stored gilthead sea bream Kyrana et al. (1997) recorded low initial pH (6.10–6.20) in the muscle. After 1 week the pH began to increase to the final value of 6.60.

Although some failures had been reported for the Torrymeter application in the shelf-life study (Kent and Oehlenschläger, 2009), the Torrymeter was found to be a suitable instrument for freshness assessment of whole fish in the present and in various studies over the years (Pivarnik et al., 1990; Sakaguchi and Koike, 2002; Lougovois et al., 2003; Oehlenschläger, 2003; Šimat et al., 2009b). The operational ‘value’ range of the Torrymeter is governed by the dielectric range of the fish and may be used to indicate the spoilage process and remaining shelf-life in whole fresh fish (Vaz-Pires et al., 1995). Each fish species would have a different range of dielectric properties. Lougovois et al. (2003) suggested that values 2 than 11 would indicate very fresh farmed gilthead sea bream fish (4 days on ice) and that a value of six would be marginal; however, the lipid content, which could explain the differences between the data, was not reported in the Lougovois et al. (2003) paper.

The values of TBA did not reach the quantity generally considered the limit of acceptability for fish (5–8 mg MA per kg) (Núñez et al., 1992) and were in range of the previously reported TBA levels of farmed Sparidae species 0.37–1.42 mg MA per kg (Tejada and Huidobro, 2002; Cakli et al., 2007; Abbas et al., 2008). The difference in rancidity between wild and farmed sea bream was expected, due to the difference in lipid content; however, oxidation spoilage did not occur in either wild or farmed samples during storage.

Fresh fish contain 5–20 mg TVB-N/100 g and 2–4 mg TMA-N/100 g (Shakila et al., 2003) while levels of 30–35 mg TVB-N/100 g and 5–10 mg TMA-N/100 g are considered the limit of acceptability for most marine fish species (Ababouch et al., 1991; Connell, 1995). Higher initial concentrations of TVB-N could be a result of high levels of non-protein nitrogen previously reported in the flesh of gilthead sea bream (Kyrana et al., 1997). Most studies reported the increase of TVB-N with storage time, regardless of storage conditions and the later increase in volatile amines in Sparidae species over the limit of acceptance after 20 days of storage in ice (Kyrana et al., 1997; Tejada and Huidobro, 2002; Cakli et al., 2007; Özogul et al., 2007). Some authors suggested that existing regulations should be adopted in the way the gilthead
sea bream is included in the group of fish for which the TVB-N level of acceptance for human consumption is set at 25 mg per 100 g (Kyrawn et al., 1997; Tjejada and Huidobro, 2002; Grigorakis et al., 2003; Ozingol et al., 2007). TMA-N comes from the reduction of trimethylamine oxide (TMAO) by bacterial activity (Dalgaard, 2003), and levels found in the aerobically stored fresh fish rejected by the sensory panel vary between 10 and 15 mg per 100 g (Dalgaard et al., 1993). The low concentrations and slow increase of TMA-N observed in our study could be explained by low TMAO concentrations found in gilthead sea bream (Kyrawn et al., 1997). Low increase of TMA-N with storage was observed in other Sparidae species, 1.8–4.3 mg TMA-N/100 g was found at sensory rejection points (Kyrawn et al., 1997; Kilinc et al., 2007). Low levels of volatile amines at the end of shelf life did not reflect the spoilage evolution over storage time. The differences observed between farmed and wild samples could be related to feed differences or to initial microbial flora; however, these were not studied to support such a thesis.

PCA of sea bream samples was performed on mean values of nine quality parameters to identify their similarities and differences, plus identification of the most effective variables (sensory assessment, lipid content) and noting the relationship among the variables themselves. This affirms the use of QIM and Torry schemes as necessary in describing different freshness levels of gilthead sea bream in shelf-life studies. The PCA analysis was found very useful in determining importance of the individual parameters, clearly separating the investigated samples according to storage time and capture grounds.

In conclusion, most differences in the two fish products of the same species could be related to lipid content, and thus the feed intake and reduced activity of the farmed samples. All studied parameters showed high correlation with sensory assessment and storage time, and thus are good indicators of changes in quality during storage in ice. However, the late response of TVB-N and TMA-N in post-mortem muscle makes them less useful as indicators by themselves. Fishery products from gilthead sea bream are widely marketed, thus the differences in physical, chemical and sensory post-mortem changes between wild and farmed samples should be taken into consideration during marketing and production.

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