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On the possible effects of harvesting season and chilled storage on the fatty acid profile of the fillet of farmed gilthead sea bream (*Sparus aurata*)

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Abstract

This work examines the fatty-acid profile of the total lipids of the muscle, as the main edible portion, of farmed sea bream (*Sparus aurata*) harvested at different periods of the year and subjected to a chilled-storage process (4 °C) for one week. Neither of the variables tested (harvest period, chilled-storage time) significantly affected the quality of this nutritional component, constituting a certain guarantee of its marketability, at least with regard to this aspect of overall product quality.

Keywords: Sea bream; Fillet; Fatty acid; Chilled storage

1. Introduction

In recent years, the importance of fish as a high-quality source of nutrients for the human diet has strengthened (McCullough et al., 2002). Coinciding with this, and despite the development of new technologies, traditional fishing is undergoing a crisis caused most probably by overexploitation of fishing grounds. This is among the factors that have stirred growing interest in fish farming, which represents a steadily higher percentage of the total amount of fish consumed by humans (FAO, 2004). In the Mediterranean area, notable success has been achieved in the production of diverse species, such as sea bream and bass. Now that production technologies have been established, interest has been redirected to augmenting the quality of the product offered (Caggiano, 2000; FEAP, 2001).

Marine fish, such as gilthead sea bream (*Sparus aurata*), are a source of highly unsaturated fatty acids of the HUFA-*n*3 family, highly appreciated for human food thanks to their beneficial role in the protection against cardiovascular and other diseases (Harris, 1989; McCullough et al., 2002). The quantity of fat and the fatty-acid profile of the edible part of farmed fish depend not only on genetic factors but also on factors such as the developmental phase, environmental temperature, feed regime, composition of fats in the diet, etc. (García-Gallego & Akharbach, 1998; Grigorakis, Alexis, Taylor, & Hole, 2002; Lie, 2001; Rueda et al., 2001). Thus, to a certain point, the composition of this component can be manipulated by modifying the production process.

In addition, once the product is harvested, its quality can vary with the duration and the method of preservation before consumption. Among other aspects, polyunsaturated fatty acids can oxidize, affecting not only their nutritional quality but also organoleptic traits such as texture and flavour (Aubourg, Piñeiro, Gallardo, & Barros-Velázquez, 2005; Brannan & Erickson, 1996; Liu, Barrows, Hardy, & Dong, 2004; Pirini, Gatta, Testi, Trigari, & Monetti, 2000; Regost, Jakobsen, & Rørå, 2004; Underland, Hall, & Lingnert, 1999).

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In the present work, we monitor the evolution of the fatty-acid profile of a fillet of farm-grown gilthead sea bream chill stored (4 °C) for up to 7 days. In addition, to study the possible influence of the season/environmental temperature on the quantity and quality of body fat, we repeated the study with 6 successive harvests at the fish farm, distributed over the year and at environmental temperatures varying from 15 °C (February) to 24 °C (August).

2. Materials and methods

2.1. Fish and their maintenance at the fish farm

The gilthead sea bream used in this study came from the intensive culture in floating cages of the company ADRAPEC (Almería, Mediterranean Sea, southern Spain).

During the period immediately preceding the harvest, the fish were being fed on commercial feed from Dibaq (4.5 mm diameter) (see composition in Table 1). Throughout the experiment, the water temperature varied from 15 to 24 °C with salinity of about 41.0 ± 1.0 mg/l.

2.2. Experimental design and dissection

Fish of commercial size, taken from the general population according to the practice of the company, were killed by thermal shock and asphyxiated on being covered with ice. In each lot, 24 fish were sampled at random. After separating the skin from the muscle, and the muscle from the spinal column, the muscle was divided into several pieces that were preserved at 4 °C and, 2 h after the fish were caught, the first tests and analyses were made. Afterwards, the samples were refrigerated at 4 °C. New tests and analyses were made at 2 and 7 days of preservation (48 and 168 h, respectively).

To determine whether the fatty-acid pattern varied in the fish over the seasons, six samplings were made over the year: February (15 °C), April (18 °C), June (21 °C), August (24 °C), October (20 °C) and December (16 °C).

2.3. Analyses

Muscle composition (AOAC, 2000) (15 samples, 2 h after death of the fish).

Protein: by Kjeldahl method, digestion with sulphuric acid in a Büchi digestor and distillation with NaOH at 40%.

Fat: by gravimetry, extraction with ethylic ether by the Soxhlet method.

Moisture: by oven drying at 105 °C to constant weight (ca. 24 h).

Ash: by incineration in a muffle oven at 500 °C to constant weight (ca. 24 h).

Lipid extraction and methylation (in 5 samples at 2, 48, and 168 h post-harvest).

Muscle lipids were extracted according to Folch, Lees, and Stanley (1957). The lipid profile of the samples was prepared by gas–liquid chromatography (GLC) applied to methylated fatty acids (Rodríguez-Ruiz, El Belarbi, García Sánchez, & López Alonso, 1998). A Hewlett Packard gas chromatograph model 5890 (Hewlett Packard, Abonadle, PA) was used with N_2 as the gas carrier connected to a computerized system to store the data. The injection, in a 1/100 split, was made in a column where the stationary phase was polyethylene-glycol, together with a phenolic silicone. The capillary column was of Omegawax™ silica (Supelco, Bellefonte, PA, USA), 30 m long, 0.25 mm internal diameter with 0.25 μm thickness of film of the stationary phase.

The quantitative analysis of the fatty acids was made by comparing the retention times of the fatty acids in the chromatograms corresponding to the reaction products, with those of a standard mixture, from Matreya (Pleasant Gap, PA, USA, cat. 1177).

Table 1
Gross composition of the commercial food used in the fish-farm

Component	(%)
Moisture	4.7
Ash	9.8
Fat	23.1
Protein	53.3
Fatty acids	**% of total lipids**
14:0	0.03
15:0	2.62
16:0	15.2
16:1*n*7	4.07
17:0	1.19
16:3*n*4	0.46
16:4*n*1	0.25
18:0	4.17
18:1*n*9	14.7
18:1*n*7	2.00
18:2*n*6	19.7
18:3*n*3	2.51
18:4*n*3	1.44
20:1*n*9	2.44
20:4*n*6	0.77
20:4*n*3	0.64
20:5*n*3	4.62
22:1*n*9	2.19
21:5*n*3	0.55
22:5*n*3	0.84
22:6*n*3	8.86
Total SFA	23.3
Total MUFA	25.4
Total PUFA	40.6
Total HUFA	17.1
Total HUFA *n*3	17.0
Total *n*7	6.07
Total *n*9	19.3
Total *n*6	20.4
Total *n*3	19.5
*n*3/*n*6 ratio	0.95
*n*3/*n*9 ratio	1.01

SFA: Saturated fatty acids, MUFA: mono-unsaturated fatty acids, PUFA: polyunsaturated fatty acids; HUFA: highly unsaturated fatty acids; HUFA*n*3: highly unsaturated fatty acids of the *n*3.

2.3.1. Indices of lipid quality

From the data on the fatty-acid composition, the following were calculated:

Index of atherogenicity (IA): indicating the relationship between the sum of the main saturates and the that of the main unsaturated, the former being considered pro-atherogenic (favouring the adhesion of lipids to cells of the immunological and circulatory systems), and the latter anti-atherogenic (inhibiting the aggregation of plaque and diminishing the levels of esterified fatty acid, cholesterol, and phospholipids, thereby preventing the appearance of micro- and macrocoronary diseases) (Ulbritcth & Southgate, 1991).

$$\mathrm{AI} = [(12{:}0 + (4 \times 14{:}0) + 16{:}0)]/[\Sigma\mathrm{MUFAs} + \mathrm{PUFA}\text{-}n6 + \mathrm{PUFA}\text{-}n3]$$

Index of thrombogenicity (IT): showing the tendency to form clots in the blood vessels. This is defined as the relationship between the pro-thrombogenetic (saturated) and the anti-thrombogenetic FA (MUFA, PUFA-*n*6 y PUFA-*n*3) (Ulbritcth & Southgate, 1991).

$$\mathrm{TI} = (14{:}0 + 16{:}0 + 18{:}0)/[(0.5 \times \Sigma\mathrm{MUFAs} + 0.5 \times \mathrm{PUFA}n6 + 3 \times \mathrm{PUFA}\text{-}n3) + (\mathrm{PUFA}\text{-}n3/\mathrm{PUFA}\text{-}n6)]$$

Flesh-lipid quality (FLQ): indicating the percentage relationship in which the main HUFA-*n*3 (EPA and DHA) appear in muscle with respect to the totality of the lipids. The higher the value of this index, the greater the quality of the dietary lipid source (Abrami et al., 1992).

2.3.2. Other indices

To compare the complete fatty-acid profiles of the different samples, we used the *D*-distance coefficient of McIntire, Tinsley, and Lowry (1969) as in Person-Le Ruyet et al. (2004):

$$D(h-j) = \left(\sum_{i=1}^{n}(P_{ih} - P_{ij})^2\right)^{1/2}$$

where $D(h-j)$ is the distance between samples h and j; P_{ih} and P_{ij} are the percentages of fatty acid i in the samples h and j, for each fatty acid i.

2.3.3. Statistical treatment

An analysis of variance was made using the package SPSS 12.0. As the values from the chromatograph are indicated in percentages (binomial distribution), the data must be transformed for a normal distribution by calculating the arcsine of the square root of the radian data. The Tukey test was used to determine the possible significant differences ($p < 0.05$) among values.

3. Results

Table 2 shows the mean weight of the gilthead sea bream at each harvest, which approximates the size range marketed by the company (250–300 g). The largest sizes of fish were found in October, followed by those of April, while the smallest were collected in August and December.

The same table presents the composition of the fillets of the different fish 2 h after being killed. Roughly, 75% of the fillet was water, some 20% protein, and 2.5–3.5% fats, without major differences being found between the different harvests in absolute terms, although there were statistically significant differences in some cases.

The fatty-acid profile of the total lipids of the muscle, at 2 h post-capture, is shown in Table 3. In all cases, the predominant fatty acids were 16:0 and 18:0 among saturated ones (SFA) and 18:1*n*9 and 16:1*n*7 among monounsaturated ones (MUFA); among polyunsaturated (PUFA), the most abundant were 22C, notably DHA (22:6*n*3) and, among 20C, EPA (20:5*n*3). Noteworthy among the *n*6, was the high presence of linoleic acid (18:2*n*6) in all cases.

Within the group of main fatty acids identified, the PUFA equalled or exceeded SFA and MUFA together, except in April and August, where the high levels of 18:1*n*9 and the low levels of 22:6*n*3, respectively, somewhat altered this tendency. The total of HUFA*n*3 represents between 25% and 37% of the total of fatty acids in sea bream muscle.

By series, the *n*3 were the most abundant, followed by the *n*9 and the *n*6, with *n*3:*n*6 ratios in the range of 1.6–3.6 and *n*3:*n*9 of 1.1–2.3.

With regard to the quality indices considered, IA, IT and FLQ, the first two showed no statistical differences, inasmuch as FLQ presented its lowest values in April, August, and October, coinciding with the lows for 22:6*n*3.

Table 4 presents the values for the distance coefficient (*D*), providing an overall comparison of the profiles; the value of this index varied between a low of 5.1 in August and October (which, according to this, would be the most similar chromatograms) and 16.7 from October to June (the most different chromatograms). The mean value of *D* was close to 10.5.

Table 2
Body weight ($n = 24$) and gross muscle composition ($n = 15$) of fish from the different harvestings (water temperature)

	February (15 °C)	April (18 °C)	June (21 °C)	August (24 °C)	October (20 °C)	December (16 °C)
Body weight (g)	279.2 ± 7.5^{bc}	297.8 ± 6.2^{ab}	274.2 ± 7.8^{bc}	261.0 ± 5.6^{c}	313.8 ± 6.5^{a}	266.3 ± 8.1^{c}
Water content (%)	75.7 ± 0.4^{ab}	74.6 ± 0.3^{a}	76.6 ± 0.4^{b}	75.0 ± 0.2^{a}	75.2 ± 0.3^{b}	75.8 ± 0.3^{ab}
Ash content (%)	1.4 ± 0.1^{ab}	1.4 ± 0.1^{ab}	1.4 ± 0.1^{ab}	1.4 ± 0.1^{ab}	1.5 ± 0.1^{a}	1.4 ± 0.1^{b}
Fat content (%)	3.4 ± 0.1^{ab}	3.7 ± 0.3^{a}	2.5 ± 0.2^{c}	3.6 ± 0.6^{a}	2.8 ± 0.2^{bc}	3.1 ± 0.1^{abc}
Protein content (%)	19.7 ± 0.2^{ab}	19.4 ± 0.2^{ab}	19.2 ± 0.2^{b}	19.8 ± 0.1^{ab}	20.0 ± 0.1^{a}	20.2 ± 0.2^{a}

[a,b,c] Values in each row with different superscripts are significantly different ($P < 0.05$).

Table 3
Muscle fatty acid profiles of gilthead sea bream harvested in different seasons

% FA (TL)	Month of harvesting					
	February	April	June	August	October	December
14:0	0.1 ± 0.1^{b}	0.1 ± 0.1^{b}	0.6 ± 0.3^{ab}	1.2 ± 0.2^{a}	1.1 ± 0.1^{a}	0.8 ± 0.1^{a}
15:0	0.4 ± 0.1	0.3 ± 0.1	0.6 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1
16:0	13.9 ± 0.9^{ab}	15.2 ± 1.0^{ab}	17.1 ± 0.6^{a}	12.4 ± 0.9^{b}	13.8 ± 1.2^{ab}	12.9 ± 1.0^{ab}
16:1*n*7	2.2 ± 0.3^{b}	4.8 ± 0.6^{a}	2.8 ± 0.2^{b}	3.0 ± 0.3^{ab}	3.2 ± 0.2^{a}	2.9 ± 0.2^{b}
16:3*n*4	0.4 ± 0.1^{c}	0.7 ± 0.1^{bc}	0.4 ± 0.2^{ac}	0.9 ± 0.1^{ab}	0.7 ± 0.2^{a}	0.9 ± 0.2^{a}
16:4*n*1	0.7 ± 0.4	0.4 ± 0.1	0.2 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
17:0	0.9 ± 0.2^{a}	0.5 ± 0.1^{ab}	0.5 ± 0.1^{ab}	0.3 ± 0.1^{ab}	0.1 ± 0.1^{b}	0.1 ± 0.1^{b}
18:0	5.2 ± 0.6	4.2 ± 0.8	3.9 ± 1.3	3.9 ± 0.3	4.2 ± 0.5	4.4 ± 0.2
18:1*n*9	10.6 ± 0.6^{b}	18.4 ± 0.7^{a}	14.4 ± 1.3^{ab}	16.0 ± 1.8^{a}	14.9 ± 1.5^{ab}	12.0 ± 0.9^{b}
18:1*n*7	1.8 ± 0.1^{ab}	1.3 ± 0.3^{ab}	0.5 ± 0.1^{b}	2.3 ± 0.2^{a}	2.1 ± 0.2^{ab}	2.0 ± 0.1^{ab}
18:2*n*6	13.2 ± 0.8^{ab}	15.2 ± 1.6^{a}	12.1 ± 0.4^{abc}	9.5 ± 0.9^{c}	8.2 ± 1.1^{bc}	9.1 ± 1.4^{bc}
18:3*n*3	1.0 ± 0.2^{ab}	2.0 ± 0.1^{a}	1.0 ± 0.1^{ab}	1.6 ± 0.3^{ab}	0.8 ± 0.2^{b}	0.9 ± 0.1^{b}
18:4*n*3	0.8 ± 0.3	0.8 ± 0.3	0.2 ± 0.1	0.6 ± 0.1	0.3 ± 0.3	0.3 ± 0.1
20:1*n*9	1.2 ± 0.1^{b}	2.2 ± 0.2^{ab}	1.8 ± 0.3^{ab}	3.3 ± 0.6^{a}	3.5 ± 0.5^{a}	2.9 ± 0.3^{a}
20:4*n*6	1.5 ± 0.1^{a}	1.2 ± 0.3^{ab}	1.7 ± 0.1^{a}	0.9 ± 0.1^{b}	0.8 ± 0.1^{b}	1.7 ± 0.1^{a}
20:4*n*3	0.7 ± 0.2	0.6 ± 0.1	0.3 ± 0.1	0.6 ± 0.1	1.3 ± 0.4	0.9 ± 0.4
20:5*n*3	0.4 ± 0.1^{b}	1.2 ± 0.1^{b}	0.4 ± 0.1^{b}	4.2 ± 0.3^{a}	6.5 ± 2.2^{a}	4.6 ± 0.4^{a}
22:1*n*9	3.7 ± 0.3^{a}	4.0 ± 0.2^{a}	3.6 ± 0.1^{a}	1.9 ± 0.2^{b}	3.4 ± 0.3^{a}	2.1 ± 0.3^{b}
21:5*n*3	0.8 ± 0.2	0.6 ± 0.1	1.0 ± 0.1	0.5 ± 0.1	0.6 ± 0.1	0.7 ± 0.2
22:5*n*3	2.0 ± 0.1^{ab}	2.9 ± 0.2^{ab}	2.6 ± 0.2^{ab}	2.3 ± 0.4^{ab}	1.6 ± 0.3^{b}	3.4 ± 0.3^{a}
22:6*n*3	23.8 ± 2.0^{abc}	18.2 ± 2.8^{bc}	29.8 ± 1.6^{a}	16.4 ± 3.9^{bc}	15.6 ± 1.1^{c}	26.7 ± 3.0^{ab}
SFA[A]	20.5 ± 1.3	20.3 ± 1.7	22.7 ± 1.1	18.0 ± 1.3	19.4 ± 1.8	18.4 ± 1.0
MUFA[A]	19.4 ± 1.6^{c}	30.7 ± 1.6^{a}	23.0 ± 1.4^{bc}	27.6 ± 1.9^{ab}	27.1 ± 1.1^{abc}	21.9 ± 1.5^{bc}
PUFA[A]	45.4 ± 1.5^{ab}	43.7 ± 1.4^{ab}	49.8 ± 1.0^{ab}	39.9 ± 2.8^{ab}	36.7 ± 0.2^{b}	49.5 ± 2.7^{a}
HUFA[A]	30.7 ± 2.1^{ab}	25.8 ± 3.0^{b}	36.3 ± 1.5^{ab}	27.8 ± 2.8^{b}	26.9 ± 1.1^{b}	38.6 ± 3.2^{a}
HUFA *n*3[A]	28.5 ± 2.1^{ab}	24.2 ± 2.6^{b}	34.3 ± 1.4^{ab}	26.6 ± 2.6^{ab}	27.8 ± 1.1^{b}	36.6 ± 3.2^{a}
Total *n*7	4.0 ± 0.5	6.1 ± 1.9	3.3 ± 0.4	5.3 ± 0.5	5.3 ± 0.4	4.9 ± 0.1
Total *n*9	15.4 ± 1.1^{c}	24.6 ± 0.2^{a}	19.7 ± 1.5^{abc}	22.3 ± 1.4^{ab}	21.8 ± 0.8^{ab}	17.0 ± 1.5^{bc}
Total *n*6	14.7 ± 0.8^{ab}	16.3 ± 1.3^{a}	13.9 ± 0.4^{ab}	16.4 ± 0.4^{bc}	9.0 ± 1.2^{c}	10.8 ± 1.3^{abc}
Total *n*3	29.5 ± 1.9^{ab}	26.2 ± 2.5^{b}	35.3 ± 1.4^{ab}	28.3 ± 2.5^{ab}	26.6 ± 1.1^{b}	37.4 ± 3.1^{a}
*n*3/*n*6 ratio	2.0 ± 0.2	1.6 ± 0.3	2.6 ± 0.2	2.0 ± 0.3	3.2 ± 0.6	3.6 ± 0.7
*n*3/*n*9 ratio	2.0 ± 0.2^{ab}	1.1 ± 0.1^{b}	1.8 ± 0.2^{a}	1.3 ± 0.2^{ab}	1.2 ± 0.1^{b}	2.3 ± 0.3^{a}
IA[B]	0.23 ± 0.01	0.21 ± 0.01	0.27 ± 0.02	0.25 ± 0.02	0.29 ± 0.02	0.23 ± 0.01
IT[B]	0.18 ± 0.02	0.19 ± 0.01	0.17 ± 0.01	0.18 ± 0.04	0.19 ± 0.02	0.14 ± 0.01
FLQ[B]	24.25 ± 1.93^{ab}	19.35 ± 2.64^{b}	30.20 ± 1.54^{a}	22.60 ± 2.4^{ab}	22.07 ± 1.41^{b}	31.27 ± 3.45^{a}

[a,b,c] Values in each row with different superscripts are significantly different ($p < 0.05$).
[A] See Table 1.
[B] IA: Index of atherogenicity; IT: Index of thrombogenicity; FLQ: Fish lipid quality (see Section 2).

Table 4
Coefficient of distance *D* (McIntire et al., 1969) among the fatty acids profiles of muscle lipids of the sea bream harvested at different seasons

	February	April	June	August	October	December
February	–					
April	9.7	–				
June	7.7	13.2	–			
August	10.0	8.0	13.9	–		
October	12.2	10.4	16.7	5.1	–	
December	7.4	13.4	8.3	9.9	12.0	–

The following Tables 5a and 5f show the evolution of these values after 48 and 168 h of preservation of the fillets at 4 °C. The general situation was that the variations detected with respect to the initial values were erratic – that is, they lacked a definitive trend and in no case were especially pronounced.

Table 6 shows the values of the McIntire index (*D*) corresponding to the chromatograms compared for the sea bream collected each month and submitted to different periods of chilled preservation. The values were, on average, similar regardless of the storage time considered (5.7 between 2 and 48 h, 4.2 between 48 and 168 h, and 5.9 for the overall period: 2 vs. 168 h). A comparison of the individual harvests showed April to be most sensitive to the preservation period in terms of fatty-acid profile, although the *D* values did not differ in any of the cases.

4. Discussion

Fish consumption is increasingly recommended by health authorities, not only for its high-quality protein content, but also for being a source of fatty acids considered highly beneficial for human health (*n*3 and *n*6). Therefore, it is not surprising that there is higher demand for fish with a growing concern for the health aspects of the diet.

Aquaculture contributes a growing proportion of the fish to cover these demands. To be specific, the Mediterranean area has undergone an explosive growth in the production of some species, including gilthead sea bream, and the technological foundation is being set for the production of other species. Part of this foundation includes the need to open progressively wider markets, implying the need to pay attention to the preservation systems and their effects on product quality.

In the present work, the possible changes in the fatty-acid profile of the edible part of farmed sea bream are studied in relation to the harvest season and the duration of the refrigerated preservation (4 °C). In this geographical area, the commercial size (ration size) for the sea bream is between 250 and 300 g, which are the weights at which the fish are taken to market in the different harvests sampled. Nevertheless, we detected certain significant differences between harvests.

The highest value was found in the October sampling, just at the end of the warm season and beginning of the natural period of gonad maturation. In a comparative study of wild sea bream and specimens farmed in the Mediterranean (Greece) in different periods of the year, Grigorakis et al. (2002) also found a peak weight for farmed sea bream in their autumn sampling (November, 20 °C; in this case, there were not data for October), the period coinciding with increased gonad development. In our experiment, the sea bream began to show significant gonad development (0.35% of body weight) in this sampling, increasing their relative weight during the winter months (0.44% in December and 0.58% in February). In the April, June, and August samplings, this relationship was practically null, coinciding with the temporal pattern of gonad development described for wild sea bream (Grigorakis et al., 2002), though, according to Zohar, Billard, and Weil (1984), complete sexual maturity was not reached under the usual conditions of cage rearing.

After winter (April), there was another weight loss, also detected in the above-mentioned study by Grigorakis et al. (2002) – in our case with an environmental temperature of 18 °C, in theirs 16 °C. In both cases, subsequent temperature increases were accompanied by a weight loss of the sea breams to a low in August (24 °C in Spain, 25 °C in Greece). Changes in environmental temperature directly affect basal metabolic rates in the ectothermal fish, and thus weight loss is not surprising during the warmer months if food intake does not vary.

The muscle composition, the main edible part of the fish, shows little seasonal differences (Table 2). The protein content proved very stable, close to 20%. This stability of the protein content of the fish has been reported for several species, including gilthead sea bream (Grigorakis et al., 2002; Rueda et al., 1997). This could be considered a parameter that, from a certain age or developmental phase, is quite fixed.

Our values for muscle-lipid content are appreciably lower than those reported by other authors for these and other species; values for this parameter are usually substantially higher in farm fish than in their wild conspecifics (Grigorakis et al., 2002; Orban, Nevigato, Di Lena, Casini, & Marzetti, 2003; Rueda et al., 2001). This result is attributed to the more regular ingestion of high-energy feed and lower expense in physical activity. The feed given to the sea bream in the present experiment contained a lipid level very similar to that used by Grigorakis et al. (2002), though these authors worked with a feed of lower protein content and, at least in theory (in no case was a direct estimate made), higher in carbohydrates. In addition, in general terms, these authors work with fish of larger size although the same authors found no relationship between body size and fat content in the muscle.

Table 5a
Evolution of muscle fatty acid composition of gilthead sea bream, harvested in February, during chilled storage (4 °C)

% FA (TL)	Hours after harvesting		
	2 h	24 h	168 h
14:0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
15:0	0.4 ± 0.1	0.5 ± 0.1	0.3 ± 0.1
16:0	13.9 ± 0.9	13.4 ± 0.4	14.9 ± 0.5
16:1*n*7	2.2 ± 0.3	2.0 ± 0.2	2.9 ± 0.5
16:3*n*4	0.4 ± 0.1	0.5 ± 0.1	0.4 ± 0.1
16:4*n*1	0.7 ± 0.4	1.9 ± 0.2	1.0 ± 0.3
17:0	0.9 ± 0.2	1.3 ± 0.2	0.8 ± 0.2
18:0	5.2 ± 0.6	4.7 ± 0.2	4.7 ± 0.2
18:1*n*9	10.6 ± 1.1	9.8 ± 0.5	12.2 ± 1.2
18:1*n*7	1.8 ± 0.2	1.7 ± 0.1	1.9 ± 0.2
18:2*n*6	13.2 ± 0.8	12.8 ± 0.5	13.3 ± 0.6
18:3*n*3	1.0 ± 0.2	0.8 ± 0.1	1.0 ± 0.1
18:4*n*3	0.8 ± 0.3	1.5 ± 0.1	1.1 ± 0.2
20:1*n*9	1.2 ± 0.1	1.1 ± 0.1	1.3 ± 0.2
20:4*n*6	1.5 ± 0.1	1.5 ± 0.1	1.4 ± 0.2
20:4*n*3	0.7 ± 0.2	0.9 ± 0.2	0.8 ± 0.1
20:5*n*3	0.4 ± 0.1	0.3 ± 0.1	0.5 ± 0.2
22:1*n*9	3.7 ± 0.3	3.6 ± 0.2	3.7 ± 0.4
21:5*n*3	0.8 ± 0.2	0.9 ± 0.3	0.9 ± 0.1
22:5*n*3	2.0 ± 0.1	2.1 ± 0.1	2.1 ± 0.1
22:6*n*3	23.8 ± 2.0	23.5 ± 0.8	22.0 ± 3.2
SFA[A]	20.5 ± 1.3	20.0 ± 0.6	20.7 ± 0.4
MUFA[A]	19.4 ± 1.6	18.1 ± 0.7	22.1 ± 1.7
PUFA[A]	45.4 ± 1.5	46.8 ± 1.1	44.6 ± 3.0
HUFA[A]	30.7 ± 2.1	32.7 ± 1.2	29.8 ± 3.3
HUFA *n*3[A]	28.5 ± 2.1	29.2 ± 1.1	27.4 ± 3.0
Total *n*7	4.0 ± 0.5	3.7 ± 0.2	4.9 ± 0.6
Total *n*9	15.4 ± 1.1	14.3 ± 0.5	17.2 ± 1.1
Total *n*6	14.7 ± 0.8	14.3 ± 0.6	14.7 ± 0.4
Total *n*3	29.5 ± 1.9	30.1 ± 1.1	28.5 ± 2.9
*n*3/*n*6 ratio	2.0 ± 0.2	2.1 ± 0.1	1.9 ± 0.2
*n*3/*n*9 ratio	2.0 ± 0.2	2.1 ± 0.1	1.7 ± 0.3
IA[B]	0.23 ± 0.01	0.22 ± 0.01	0.23 ± 0.01
IT[B]	0.18 ± 0.02	0.17 ± 0.01	0.19 ± 0.02
FLQ[B]	24.25 ± 1.93	23.75 ± 0.75	22.44 ± 3.02

[a,b,c] Values in each row with different superscripts are significantly different ($p < 0.05$).

[A] See Table 1.

[B] IA: Index of atherogenicity; IT: Index of thrombogenicity; FLQ: Fish lipid quality (see Section 2).

The seasonal variations in this component are minor, in contrast to findings of other authors who have worked with sea bream having higher muscle-lipid levels (Grigorakis et al., 2002), which were related to lipid mobilization to the developing gonads and/or with seasonal differences in feed intake. In our case, there was no direct relation detected between body size and muscle-fat content, as reported for other fish (Shearer, 1994) but not for sea bream, as indicated above (Grigorakis et al., 2002). As the water and mineral contents did not vary appreciably, either, we conclude that, from the standpoint of macronutrient composition, the quality of the product offered is quite constant over the year.

There is growing interest in the quality of the lipids of the edible fraction of fish, judged by their fatty-acid profile (Valfré, Caprino, & Turchini, 2003). In the not-too-distant future, aquaculture will become a major source of fatty acids that are very healthy for human nutrition. The gilthead sea bream examined in the present work offer a fatty-acid profile that in general follows values established in the literature for this species when experimentally fed diets with an appreciable proportion of vegetable oils (El-Kerdawy & Salama, 1997; Izquierdo et al., 2003), and somewhat different from fish fed on diets with fish oil as the only lipid source. In this comparison, a good index is provided by the total levels of HUFA*n*3 and the *n*3/*n*6 relationship, this being clearly higher in both wild fish or farmed on diets based on fish oil (Grigorakis et al., 2002). Our commercial diet must incorporate a high level of lipids of vegetable origin, given the high

Table 5b
Evolution of muscle fatty acid composition of gilthead sea bream, harvested in April, during chilled storage (4 °C)

% FA (TL)	Hours after harvesting		
	2 h	24 h	168 h
14:0	0.1 ± 0.1	0.3 ± 0.1	0.8 ± 0.3
15:0	0.3 ± 0.1	0.4 ± 0.1	0.3 ± 0.1
16:0	15.2 ± 1.0	16.1 ± 0.6	16.4 ± 0.3
16:1*n*7	4.8 ± 0.6	3.8 ± 0.7	2.9 ± 0.4
16:3*n*4	0.7 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
16:4*n*1	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
17:0	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
18:0	4.2 ± 0.8	4.8 ± 0.4	4.4 ± 0.4
18:1*n*9	18.4 ± 0.7	14.6 ± 2.0	12.0 ± 1.2
18:1*n*7	1.3 ± 0.3	2.5 ± 0.2	1.2 ± 0.4
18:2*n*6	15.2 ± 1.6	12.4 ± 1.2	10.0 ± 0.9
18:3*n*3	2.0 ± 0.1	1.3 ± 0.3	3.6 ± 0.7
18:4*n*3	0.8 ± 0.3	0.7 ± 0.1	0.4 ± 0.3
20:1*n*9	2.2 ± 0.2[a]	1.7 ± 0.3[a]	1.1 ± 0.2[b]
20:4*n*6	1.2 ± 0.3	1.4 ± 0.1	1.6 ± 0.1
20:4*n*3	0.6 ± 0.1	0.6 ± 0.1	0.3 ± 0.1
20:5*n*3	1.2 ± 0.1	0.8 ± 0.1	0.4 ± 0.1
22:1*n*9	4.0 ± 0.2	4.1 ± 0.3	4.0 ± 0.2
21:5*n*3	0.6 ± 0.1	0.9 ± 0.1	1.0 ± 0.4
22:5*n*3	2.9 ± 0.2	2.7 ± 0.1	2.8 ± 0.1
22:6*n*3	18.2 ± 2.8	24.0 ± 4.6	28.4 ± 3.8
SFA[A]	20.3 ± 1.7	22.0 ± 0.9	22.4 ± 0.7
MUFA[A]	30.7 ± 1.6	26.6 ± 3.4	22.1 ± 1.8
PUFA[A]	43.7 ± 1.4	46.0 ± 2.9	46.8 ± 2.9
HUFA[A]	25.8 ± 3.0	31.8 ± 4.4	35.1 ± 3.4
HUFA *n*3[A]	24.2 ± 2.6	30.2 ± 4.3	33.2 ± 3.4
Total *n*7	6.1 ± 1.9	6.3 ± 0.9	5.0 ± 0.4
Total *n*9	24.6 ± 0.2	20.4 ± 2.6	17.1 ± 1.4
Total *n*6	16.3 ± 1.3	13.8 ± 1.1	11.6 ± 1.0
Total *n*3	26.2 ± 2.5	31.5 ± 4.1	34.3 ± 3.2
*n*3/*n*6 ratio	1.6 ± 0.3	2.4 ± 0.5	3.1 ± 0.5
*n*3/*n*9 ratio	1.1 ± 0.1	1.7 ± 0.5	2.1 ± 0.3
IA[B]	0.21 ± 0.01	0.24 ± 0.01	0.29 ± 0.01
IT[B]	0.19 ± 0.01	0.18 ± 0.01	0.18 ± 0.01
FLQ[B]	19.35 ± 2.64	25.52 ± 4.49	28.80 ± 3.66

[a,b,c] Values in each row with different superscripts are significantly different ($p < 0.05$).
[A] See Table 1.
[B] IA: Index of atherogenicity; IT: Index of thrombogenicity; FLQ: Fish lipid quality (see Section 2).

Table 5c
Evolution of muscle fatty acid composition of gilthead sea bream, harvested in June, during chilled storage (4 °C)

% FA (TL)	Hours after harvesting		
	2 h	24 h	168 h
14:0	0.6 ± 0.3	0.8 ± 0.2	0.8 ± 0.1
15:0	0.6 ± 0.1	0.4 ± 0.1	0.7 ± 0.3
16:0	17.1 ± 0.6	16.5 ± 0.8	18.3 ± 0.3
16:1*n*7	2.8 ± 0.2[a]	1.8 ± 0.4[b]	2.0 ± 0.1[ab]
16:3*n*4	0.4 ± 0.2	0.6 ± 0.1	0.5 ± 0.1
16:4*n*1	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.1
17:0	0.5 ± 0.1	0.6 ± 0.2	0.4 ± 0.2
18:0	3.9 ± 1.3	5.8 ± 0.3	7.1 ± 0.7
18:1*n*9	14.4 ± 1.3[a]	10.0 ± 1.0[b]	13.3 ± 0.3[ab]
18:1*n*7	0.5 ± 0.1	2.4 ± 0.6	0.3 ± 0.3
18:2*n*6	12.1 ± 0.4	10.9 ± 0.7	11.2 ± 0.2
18:3*n*3	1.0 ± 0.1[a]	0.6 ± 0.1[ab]	0.3 ± 0.2[b]
18:4*n*3	0.2 ± 0.1	0	0
20:1*n*9	1.8 ± 0.3	0.9 ± 0.1	0.7 ± 0.2
20:4*n*6	1.7 ± 0.1	2.0 ± 0.2	2.3 ± 0.2
20:4*n*3	0.3 ± 0.1	0.2 ± 0.1	0
20:5*n*3	0.4 ± 0.1	0.4 ± 0.1	0.8 ± 0.8
22:1*n*9	3.6 ± 0.1	3.5 ± 0.4	2.2 ± 0.9
21:5*n*3	1.0 ± 0.1	1.2 ± 0.2	0.9 ± 0.3
22:5*n*3	2.6 ± 0.2	2.5 ± 0.3	2.2 ± 0.2
22:6*n*3	29.8 ± 1.6	33.4 ± 3.0	32.8 ± 0.7
SFA[A]	22.7 ± 1.1[b]	24.0 ± 0.9[ab]	27.2 ± 0.8[a]
MUFA[A]	23.0 ± 1.4	18.5 ± 1.9	18.5 ± 1.2
PUFA[A]	49.8 ± 1.0	52.0 ± 3.1	51.3 ± 1.7
HUFA[A]	36.3 ± 1.5	40.0 ±3.7	39.3 ± 1.6
HUFA *n*3[A]	34.3 ± 1.4	37.7 ± 3.4	36.8 ± 1.5
Total *n*7	3.3 ± 0.4	4.1 ± 0.9	2.3 ± 0.4
Total *n*9	19.7 ± 1.5[a]	14.4 ± 1.0[b]	16.2 ± 1.1a[b]
Total *n*6	13.9 ± 0.4	12.9 ± 0.5	13.4 ± 0.3
Total *n*3	35.3 ± 1.4	38.3 ± 3.4	37.1 ± 1.5
*n*3/*n*6 ratio	2.6 ± 0.2	3.0 ± 0.3	2.8 ± 0.1
*n*3/*n*9 ratio	1.8 ± 0.2	2.7 ± 0.4	2.3 ± 0.2
IA[B]	0.27 ± 0.02	0.28 ± 0.02	0.32 ± 0.01
IT[B]	0.17 ± 0.01	0.17 ± 0.01	0.20 ± 0.01
FLQ[B]	30.20 ± 1.51	33.77 ± 3.00	33.59 ± 1.37

[a,b,c] Values in each row with different superscripts are significantly different ($p < 0.05$).
[A] See Table 1.
[B] IA: Index of atherogenicity; IT: Index of thrombogenicity; FLQ: Fish lipid quality (see Section 2).

proportion of linoleic acid (18:2*n*6) and, to a lesser extent, oleic (18:1*n*9).

One of the main exogenous determinants of the composition of body lipids in fish is diet, this becoming evident whether comparing wild with farmed specimens (Krajnović-Ozretić, Najdek, & Ozretić, 1994; Orban et al., 2003; Rodríguez et al., 2004; Rueda et al., 1997, 2001) or whether comparing fish fed diets with different lipid sources (El-Kerdawy & Salama, 1997; García-Gallego & Akharbach, 1998; Izquierdo et al., 2003; Izquierdo et al., 2005; Kalogeropoulos, Alexis, & Henderson, 1993; Person-Le Ruyet et al., 2004), although these effects can be far more pronounced in some body components than in others (Izquierdo et al., 2005).

With respect to the possible seasonal changes, the effects of environmental variables such as temperature and salinity have been studied in relation to the fatty-acid profile of lipids in different species of fish (Cordier, Brichon, Weber, & Zwingelstein, 2002; Delgado, Estévez, Hortelano, & Alejandre, 1994; Poli et al., 2003; Tocher & Sargent, 1990). These changes, when detected, appear to be more marked in the polar lipid structures than in the neutral lipids of reserve, insinuating an increase in the degree of unsaturation as temperature falls or salinity rises, though the data are not consistent in all the cases and are conditioned by the origin of the fish (wild or farmed), thereby reinforcing the determining role of diet in their lipid composition.

Therefore, if, as in our case, the feeding pattern does not change remarkably in qualitative terms, over the year the possible seasonal changes in the absolute content in lipids need not be accompanied by changes in their fatty-acid

Table 5d
Evolution of muscle fatty acid composition of gilthead sea bream, harvested in August, during chilled storage (4 °C)

% FA (TL)	Hours after harvesting		
	2 h	24 h	168 h
14:0	1.2 ± 0.2	0.9 ± 0.2	1.1 ± 0.2
15:0	0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.1
16:0	12.4 ± 0.9	12.1 ± 0.8	12.6 ± 1.0
16:1*n*7	3.0 ± 0.3	3.1 ± 0.3	3.1 ± 0.3
17:0	0.9 ± 0.1[b]	1.5 ± 0.1[a]	1.6 ± 0.2[a]
16:3*n*4	0.4 ± 0.1	0.2 ± 0.1	0.3 ± 0.1
16:4*n*1	0.3 ± 0.1	0.4 ± 0.1	0.3 ± 0.1
18:0	3.9 ± 0.3	4.3 ± 0.3	4.2 ± 0.3
18:1*n*9	17.0 ± 1.0	15.7 ± 1.7	16.2 ± 1.3
18:1*n*7	2.3 ± 0.2	2.4 ± 0.1	2.4 ± 0.1
18:2*n*6	9.5 ± 0.9	14.6 ± 2.2	15.21 ± 1.4
18:3*n*3	1.6 ± 0.3	1.5 ± 0.3	1.7 ± 0.2
18:4*n*3	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1
20:1*n*9	3.3 ± 0.6	3.3 ± 0.1	3.6 ± 0.2
20:4*n*6	0.9 ± 0.1	0.8 ± 0.1	1.0 ± 0.1
20:4*n*3	0.6 ± 0.1	0.6 ± 0.1	0.8 ± 0.1
20:5*n*3	4.2 ± 0.3	4.0 ± 0.3	4.1 ± 0.2
22:1*n*9	1.9 ± 0.2	2.5 ± 0.2	2.7 ± 0.4
21:5*n*3	0.5 ± 0.1	0.5 ± 0.1	0.6 ± 0.1
22:5*n*3	2.3 ± 0.4	2.4 ± 0.1	2.5 ± 0.1
22:6*n*3	16.4 ± 3.9	16.6 ± 2.1	16.9 ± 2.3
SFA[A]	18.0 ± 1.3	17.9 ±1.0	18.3 ± 1.2
MUFA[A]	27.6 ± 1.9	27.0 ± 1.9	27.9 ± 1.9
PUFA[A]	39.9 ± 2.8	43.4 ± 1.1	45.1 ± 1.3
HUFA[A]	27.8 ± 2.8	25.8 ± 2.5	26.7 ± 2.6
HUFA *n*3[A]	26.6 ± 2.6	24.7 ± 2.4	25.5 ± 2.5
Total *n*7	5.3 ± 0.5	5.4 ± 0.3	5.5 ± 0.3
Total *n*9	22.3 ± 1.4	21.6 ± 1.7	22.4 ± 1.6
Total *n*6	10.4 ± 0.9	15.4 ± 2.2	16.1 ± 1.3
Total *n*3	28.3 ± 2.5	26.2 ± 2.1	27.2 ± 2.3
*n*3/*n*6 ratio	2.8 ± 0.3	1.8 ± 0.3	1.7 ± 0.3
*n*3/*n*9 ratio	1.3 ± 0.2	1.2 ± 0.2	1.2 ± 0.17
IA[B]	0.25 ± 0.02	0.23 ± 0.01	0.24 ± 0.02
IT[B]	0.18 ± 0.04	0.17 ± 0.01	0.18 ± 0.02
FLQ[B]	22.60 ± 2.44	20.68 ± 2.36	20.99 ± 2.42

[a,b,c] Values in each row with different superscripts are significantly different ($p < 0.05$).
[A] See Table 1.
[B] IA: Index of atherogenicity; IT: Index of thrombogenicity; FLQ: Fish lipid quality (see Section 2).

Table 5e
Evolution of muscle fatty acid composition of gilthead sea bream, harvested in October, during chilled storage (4 °C)

% FA (TL)	Hours after harvesting		
	2 h	24 h	168 h
14:0	1.1 ± 0.1	0.7 ± 0.1	1.1 ± 0.2
15:0	0.2 ± 0.1	0.6 ± 0.3	0.2 ± 0.1
16:0	13.8 ± 1.2	15.0 ± 2.4	14.3 ± 1.1
16:1*n*7	3.2 ± 0.2	2.9 ± 0.1	3.0 ± 0.1
16:3*n*4	0.7 ± 0.2	1.2 ± 0.1	1.1 ± 0.1
16:4*n*1	0.3 ± 0.1	0.7 ± 0.3	0.3 ± 0.1
17:0	0.1 ± 0.1	0..3 ± 0.1	0.3 ± 0.1
18:0	4.2 ± 0.5	5.3 ± 0.9	4.7 ± 0.3
18:1*n*9	14.9 ± 1.5[a]	11.9 ± 0.6[b]	14.8 ± 0.5[a]
18:1*n*7	2.1 ± 0.2	1.9 ± 0.1	2.5 ± 0.1
18:2*n*6	8.2 ± 1.1	8.3 ± 0.7	8.8 ± 0.8
18:3*n*3	0.8 ± 0.2	0.7 ± 0.1	1.0 ± 0.2
18:4*n*3	0.3 ± 0.3	0.6 ± 0.1	0.5 ± 0.1
20:1*n*9	3.5 ± 0.5	3.0 ± 0.3	4.3 ± 0.2
20:4*n*6	0.8 ± 0.1[b]	1.1 ± 0.1[a]	1.0 ± 0.1[a]
20:4*n*3	1.3 ± 0.4	1.2 ± 0.3	0.9 ± 0.2
20:5*n*3	6.5 ± 2.2	5.2 ± 0.4	4.8 ± 0.2
22:1*n*9	3.4 ± 0.3	4.6 ± 1.4	3.6 ± 0.4
21:5*n*3	0.6 ± 0.1	0.2 ± 0.2	0.5 ± 0.1
22:5*n*3	1.6 ± 0.3[b]	1.9 ± 0.6[ab]	2.6 ± 0.3[a]
22:6*n*3	15.6 ± 1.1[b]	20.0 ± 1.3[a]	17.3 ± 1.3[a]
SFA[A]	19.4 ± 1.8	21.9 ± 3.8	20.8 ± 1.4
MUFA[A]	27.1 ± 1.1	24.3 ± 1.2	28.2 ± 1.2
PUFA[A]	36.7 ± 0.2	40.7 ± 2.3	38.8 ± 2.2
HUFA[A]	26.9 ± 1.1	30.4 ± 2.7	27.9 ± 1.4
HUFA *n*3[A]	27.8 ± 1.1	28.6 ± 2.3	26.5 ± 1.5
Total *n*7	5.3 ± 0.4	4.8 ±0.1	5.6 ± 0.2
Total *n*9	21.8 ± 0.8	19.4 ± 1.2	22.7 ± 1.0
Total *n*6	9.0 ± 1.2[c]	9.4 ± 0.6	9.9 ± 0.8
Total *n*3	26.6 ± 1.1	29.3 ± 2.4	27.5 ± 1.5
*n*3/*n*6 ratio	3.2 ± 0.6	3.2 ± 0.4	2.8 ± 0.1
*n*3/*n*9 ratio	1.2 ± 0.1	1.5 ± 0.2	1.2 ± 0.1
IA[B]	0.29 ± 0.02	0.28 ± 0.05	0.29 ± 0.03
IT[B]	0.19 ± 0.02	0.20 ± 0.05	0.19 ± 0.02
FLQ[B]	17.21 ± 1.41	25.11 ± 1.57	22.04 ± 1.68

[a,b,c] Values in each row with different superscripts are significantly different ($p < 0.05$).
[A] See Table 1.
[B] IA: Index of atherogenicity; IT: Index of thrombogenicity; FLQ: Fish lipid quality (see Section 2).

Table 5f
Evolution of muscle fatty acid composition of gilthead sea bream, harvested in December, during chilled storage (4 °C)

% FA (TL)	Hours after harvesting		
	2 h	24 h	168 h
14:0	0.8 ± 0.1^{b}	1.4 ± 0.1^{a}	1.4 ± 0.1^{a}
15:0	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
16:0	12.9 ± 1.0	12.6 ± 1.1	14.32 ± 1.0
16:1*n*7	2.9 ± 0.2	2.8 ± 0.1	2.8 ± 0.2
16:3*n*4	0.9 ± 0.2	1.5 ± 0.2	1.3 ± 0.1
16:4*n*1	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1
17:0	0.1 ± 0.1	0.4 ± 0.1	0.3 ± 0.1
18:0	4.4 ± 0.2	3.8 ± 0.1	4.0 ± 0.4
18:1*n*9	$12. \pm 0.9$	11.6 ± 0.7	11.8 ± 0.8
18:1*n*7	2.0 ± 0.1	2.2 ± 0.1	1.7 ± 0.6
18:2*n*6	9.1 ± 1.4	7.5 ± 0.9	7.7 ± 0.9
18:3*n*3	0.9 ± 0.1	1.0 ± 0.1	0.9 ± 0.1
18:4*n*3	0.3 ± 0.1	0.6 ± 0.1	0.6 ± 0.1
20:1*n*9	2.9 ± 0.3	3.4 ± 0.2	3.3 ± 0.2
20:4*n*6	1.7 ± 0.1	2.4 ± 0.7	1.7 ± 0.2
20:4*n*3	0.9 ± 0.4	1.5 ± 0.2	1.7 ± 0.5
20:5*n*3	4.6 ± 0.4^{b}	5.8 ± 0.3^{a}	5.1 ± 0.2^{ab}
22:1*n*9	2.1 ± 0.3	2.8 ± 0.2	2.3 ± 0.4
21:5*n*3	0.7 ± 0.2	0.7 ± 0.1	0.7 ± 0.1
22:5*n*3	3.4 ± 0.3	3.2 ± 0.2	2.8 ± 0.1
22:6*n*3	26.7 ± 3.0	22.4 ± 0.6	22.1 ± 1.7
SFA[A]	18.4 ± 1.0	18.2 ± 1.3	20.0 ± 1.4
MUFA[A]	21.9 ± 1.5	22.8 ± 1.1	21.8 ± 1.7
PUFA[A]	49.5 ± 2.7	47.0 ± 1.4	44.9 ± 2.1
HUFA[A]	38.6 ± 3.2	37.0 ± 1.1	35.0 ± 2.0
HUFA *n*3[A]	36.6 ± 3.2	34.2 ± 0.5	33.1 ± 2.1
Total *n*7	4.9 ± 0.1	5.0 ± 0.2	4.4 ± 0.7
Total *n*9	17.0 ± 1.5	17.8 ± 0.9	17.3 ± 1.1
Total *n*6	10.8 ± 1.3	9.9 ± 0.9	9.4 ± 1.1
Total *n*3	37.4 ± 3.1	35.2 ± 0.6	34.0 ± 2.0
*n*3/*n*6 ratio	3.6 ± 0.7	3.6 ± 0.3	3.7 ± 0.4
*n*3/*n*9 ratio	2.3 ± 0.3	2.0 ± 0.1	2.0 ± 0.2
IA[B]	0.23 ± 0.01	0.27 ± 0.03	0.31 ± 0.03
IT[B]	0.14 ± 0.01	0.14 ± 0.01	0.16 ± 0.02
FLQ[B]	31.27 ± 3.45	28.20 ± 0.43	27.29 ± 1.89

[a,b,c] Values in each row with different superscripts are significantly different ($p < 0.05$).
[A] See Table 1.
[B] IA: Index of atherogenicity; IT: Index of thrombogenicity; FLQ: Fish lipid quality (see Section 2).

Table 6
Effects of duration of refrigerated conservation on the coefficient of distance *D* (McIntire et al., 1969) among the fatty acids profiles of muscle lipids of the sea bream harvested at different seasons

Hours after harvesting	Month of harvesting					
	February	April	June	August	October	December
2 vs. 48	2.7	8.4	6.6	5.7	6.0	5.1
2 vs. 168	2.4	13.5	5.2	6.0	3.0	5.2
48 vs. 168	3.6	5.2	5.2	6.0	3.0	2.2

profile, especially if we examine the total lipids, among which the reserve (triglycerides) represent the majority.

The time interval between killing (harvesting) at the fish farm and consumption by humans can involve the alteration of some organoleptic and nutritional characteristics. Clearly, the magnitude of these alterations depends on the length of this time interval and on the technology used for preserving the fish (e.g. chilling, smoking, freezing, canning,...). Thus, for example, negative changes can occur in the physical properties of the muscle (Nunes, Batista, & Morao de Campos, 1992; Olafsdóttir et al., 1997). In a study parallel to the present one, with the same species, we have shown the temporal sequence of changes in the collagen content, the water-holding ability (WHA), and the firmness or softness of the fillet during chilled storage (4 °C) of up to 120 h (Suárez, Abad, Ruiz-Cara, Estrada, & García-Gallego, 2005). In this respect, Huidobro, Mendes, and Nunes (2001) reported the beneficial effect of killing sea bream on slurry ice, as in this experiment.

One of the nutritional components of the fish fillet which are the most sensitive to deterioration is fat, which can undergo hydrolysis and consequently an increase in the proportion of free fatty acids (FFA). This can deteriorate the texture of the product and result in oxidation or rancidity, which can negatively affect the flavour (Losada, Piñeiro, Barros-Velázquez, & Aubourg, 2005; Sargent, Tocher, & Bell, 2002). Several authors have reported on the effect of different chilled-storage systems on these parameters. Losada et al. (2005), comparing storage in slurry ice with respect to traditional flake ice up to 22 days with fresh horse mackerel (*Trachurus trachurus*), found that slurry ice significantly inhibited the deterioration processes, including hydrolysis and lipid oxidation. Aubourg et al. (2005), after preserving pieces of muscle of farmed turbot (*Psetta maxima*) at 4 °C for up to 29 days, detected a higher content in FFA from day 9, which peaked on day 26. Both this process as well as lipid peroxidation proved slower in this species than in others. In any case, for these and other changes, both in the composition as well as in other characteristics (aspect of the skin, external odour), the sensory quality seriously declined from day 14 of storage.

The effects of storage on the quality of the muscle lipids in fish has been demonstrated to be dependent on dietary elements, such as vitamin E, which in several species protects against peroxidation and putrefaction (see references in Pirini et al., 2000). Nevertheless, these same authors in their study on sea bass observed that diets supplemented with progressively higher levels of vitamin E (100–800 ppm) produced fish with gradually higher levels of this vitamin in their muscle. Meanwhile, Onibi, Scaife, Fletcher, and Houlihan (1996) reported that, in salmon preserved at 4 °C, muscle samples refrigerated at 1 °C for up to 12 days showed no apparent changes in the characteristics of their lipid component regardless of the vitamin-E level in the diet or in the muscle, as opposed to what might be expected. These authors point out that in their experiment, apart from using a lower temperature they took additional precautions such as to avoid light and oxygen, environmental factors that could have accelerated lipid degradation.

In any case, Pirini et al. (2000) found no significant differences in the fatty-acid profile of muscle lipids and therefore in nutritional quality (measured with IA and IT) over

the entire storage period. In one study on the influence of time on the quality of frozen salmon fillets they cite, among many other data on compositional and organoleptic parameters, a relative stability in the fatty-acid profile after 4 months of frozen storage, confirming previous results of Polvi, Ackman, Lall, and Saunders (1991) with the same species, although no specific data were provided. More recently, Roldán, Roura, Montecchia, Borla, and Crupkin (2005) did detect a certain effect of storage after freezing in hake (*Merluccius merluccius*) fillets consisting of a decline in the $n-3$ fatty-acid content, this being more marked in prespawned fish.

In line with some of the above findings, after storage at 4 °C for 7 days, the muscle of our farmed sea bream did not appear to undergo significant changes in fatty-acid profile or, therefore, in the quality of these lipids measured by the three indices used (Tables 5a–5f). On the other hand, as might be expected, the possible overall differences due to the extension of the storage period (Index D, Table 6) were smaller than those found between the sea bream of different harvests, although, as commented above, these were not very notable, either. The highest *D* values corresponded to sea bream in April, a finding which could be considered indicative of higher sensitivity of these fish to the storage process. We have no plausible explanation for this fact. In addition, this was one of the groups of sea bream with the lowest presence of DHA, one of the HUFAs most sensitive a priori to the degradation process.

The main conclusions of this study are: (i) that the quality of the lipid component of the edible part of farmed sea bream remains constant over the entire year, provided that, as in this case, no major changes occur in the production process, especially in the quality of the feed provided to the fish; and (ii) that chilled storage (4 °C) does not negatively alter this quality indicator at least during the first 7 days.

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