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SCIENCE DIRECT
Food Chemistry 100 (2007) 1504–1510
Food Chemistry
www.elsevier.com/locate/foodchem

Feeding interruption and quality of cultured gilthead sea bream

J. Ferreira Pinto *, M.L. Nunes, C. Cardoso

Departamento de Inovação Tecnológica e Valorização dos Produtos da Pesca, IPIMAR, Avenida de Brasília, P-1449-006 Lisboa, Portugal

Received 5 September 2005; accepted 29 November 2005

Abstract

Proximate composition, fatty acid and amino acid profiles and sensory attributes of semi-intensive cultured gilthead sea bream were determined without feeding interruption and with feeding interruption from 1 to 13 days. Average proximate composition was protein: 19.4–19.9%, fat 14.1–15.4%, moisture: 64.1–65.3%, and ash: 1.3%. The monounsaturated fatty acids (MUFA) were dominant: 43%, followed by polyunsaturated fatty acids (PUFA): 32% and saturated fatty acids (SFA) 25%. For each fatty acid class the major compounds were palmitic acid (SFA), vaccenic and oleic acid (MUFA) and docosahexaenoic acid (PUFA). Regarding the feeding interruption, it appears that the perivisceral fat can supply the required energy for up to 13 days of starvation.

Keywords: Gilthead sea bream; Feeding interruption; Proximate composition; Fatty acids; Amino acids; Sensory analysis; Aquaculture; Semi-intensive; Portugal

1. Introduction

A growing percentage of human fish consumption is supported by aquaculture (FAO, 2005). Fish farming in the Mediterranean has undergone a spectacular growth in a time span of less than a decade (Kaushik, 1997). Within European farmed fish species, gilthead sea bream, (*Sparus aurata*, L.) is highly valued by southern European consumers, accounting for its economic importance in this area (Grigorakis, Taylor, & Alexis, 2003a, 2003b). Consequently, intensive and semi-intensive gilthead sea bream production has increased significantly in the past years (Flos, Reig, Oca, & Ginovart, 2002; Huidoboro & Tejada, 2004). Semi-intensive farming involves administration of feeds and is usually done in salt marshes (NACA/FAO, 2001). Several authors have described chemical composition and sensorial features of cultured sea bream. However, comparative data on fish obtained from different culture systems is scarce (Acierno et al., 2003; Flos et al., 2002). Moreover, feeding interruption before slaughtering is frequently not mentioned despite the fact that it is a standard procedure. As an exception, Flos et al. (2002), Huidoboro, Pastor, López-Caballero, and Tejada (2001), and Huidoboro and Tejada (2004) mentioned periods of 24 and 48 h of feeding interruption, in order to empty the gastrointestinal tract of the fish. By reducing the amount of faeces in the intestines, spoilage is delayed and digestive enzyme activity is reduced, after *rigor mortis* has occurred. If further processing steps are considered, e.g. filleting and freezing, feeding interruption may be a determinant of product shelf life (Huidoboro & Tejada, 2004). Literature on sea bream production considers the right combination of feed ingredients, in order to maximize fish growth and health, while minimising waste and price of feed (Asknes, Izquierdo, Robaina, Vergara, & Montero, 1997; Cowey & Cho, 1991; Hasan, 2001); gilthead sea bream's market specificity and seasonality (Huidoboro & Tejada, 2004); the need for diversification of aquaculture species (Basurco & Abellán, 1999; Hernández, Martinez, & García García, 2001) and product marketing (Bermejo, 2000). Farmed fish, as any other product, are fed for quality and therefore to meet consumer needs (nutritional and safety) and expectations (taste and flavour) (Hough, 2000; ISO, 2000). If similarity to wild gilthead

* Corresponding author. Tel.: +351 21 302 7034; fax: +351 21 301 5948.
E-mail address: ditvpp@gmail.com (J. Ferreira Pinto).

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doi:10.1016/j.foodchem.2005.11.041

sea bream is requested (market driven), then feeding interruption before harvest may be applied beyond 48 h, in order to ameliorate fish characteristics. This research was to characterize the proximate chemical composition and lipid profile of gilthead sea bream farmed in a land-based semi-intensive aquaculture system. Also, to determine the effect of feeding interruption on gilthead sea bream proximate chemical composition, lipid profile and consumer appreciation (sensory evaluation).

2. Materials and methods

2.1. Questionnaire on feeding interruption

Farmers answered a simple questionnaire, in order to assess the use of feeding interruption (FI) before slaughtering in the area where the study was performed. This was designed to provide answers regarding the use of FI and to assess the number of days to starve fish and the reasons why. Eleven aquaculturists, who accounted for most of the aquaculture production at Sado's estuary, Portugal, were interviewed and answers were registered.

2.2. Feed

Fish were fed with a commercial extruded feed, with an average composition of 44% protein, 11% ash, 25% fat, 10.5% of carbohydrates and 1.5% of fibre. Feeding until the beginning of the experiment was carried out according to feed manufacturer instructions (Dourasoja, SORGAL, SA).

2.3. Sampling

The fish, gilthead sea bream (*Sparus aurata*, L.), were obtained from a commercial fish farm (former salt pond) located at Sado's estuary, Portugal. Sampling took place during September when fish had reached the desired commercial weight. Fish were maintained in the same tanks prior to their slaughter. Four different feeding interruption periods – one, two (the usual period), seven and thirteen days – were compared. From the commercial catch, a total of 56 adult fish were collected randomly, 14 on each day. Fish were killed by hypothermia (fish immersion in iced water), which caused the fish body temperature to fall to 1–2 °C. Then, fish were packed with flaked ice into polystyrene boxes and delivered to the laboratory within 3–4 h of harvesting.

2.4. Sample preparation

Samples for sensory evaluation (4 fish) were frozen and then stored at −80 °C until analysis. The other 10 fish were skin-on filleted, packed, frozen and stored at −80 °C until analysis (within 10–15 days). The material used for chemical analysis was a mince prepared with skin-on fillets, and for colour measurements was a skinless mince. The proximate composition was measured in the anterior (A) and posterior part (B) of the fillet, with the fillet being split into two equal portions. Perivisceral fat (V) of each individual was also collected and kept frozen until further analysis.

2.5. Analysis

2.5.1. Proximate composition

Moisture, protein, fat and ash contents were determined according to the methods described in AOAC (1990).

2.5.2. Fatty acids

Fatty acid profile determination was done according to the procedure described by Lepage and Roy (1986) and modified by Cohen, Vong Shak, and Richmond (1988). The fatty acid methyl esters were analysed in a Varian 3400 gas chromatograph, equipped with an auto-sampler and fitted with a flame ionisation detector. The separation was carried out with helium as carrier gas in a fused silica capillary column Chrompack CPSil/88 (50 m × 0.32 mm i.d., film thickness: 0.20 μm). With a temperature program starting at 180 °C for 5 min, heating at 4 °C/min for 10 min and holding at 220 °C for 25 min. Split injection (100:1) at 250 °C was used. Fatty acid methyl esters were identified by comparison of their retention time with those of Sigma chromatographic standards. Peak areas were determined using the Varian software.

2.5.3. Total amino acids

Total amino acid composition was determined using an amino acid analyser (Biochrom 20, Pharmacia Biotech, Sweden). Samples were hydrolysed in 6 M HCl in evacuated sealed tubes at 110 °C for 24 h. The detection was at 440 and 570 nm after reaction with ninhydrin. Amino acids were identified by comparison of their retention times with those of standards (Sigma) and quantified with the software EZChrom™ Chromatography Data System version 6.7, using norleucine (Sigma) as internal standard.

2.5.4. Colour

Fish muscle without skin was used for colour measurements in a MACBETH COLOR-EYE® 3000 colorimeter. The L^*, a^* and b^* parameters (CIELab system) were obtained, and the intensity of colour was expressed by chroma value, which was calculated according to the formula: chroma $= [a^{*2} + b^{*2}]^{1/2}$ (Botta, 1995).

2.5.5. Sensory assessment

Sensory affective assessment was performed using a QIM (Quality Index Method) developed at IPIMAR for sea bream, based on that published by Gonçalves, Mendes, and Nunes (2004), describing features for general appearance, eyes and gills. Four experienced panellists were selected for this assessment and data was analysed as described by Laramond (1970). Cooked fish were assessed according to the simplified Torry Sensory Scheme for white fish fillets (Whittle, Hardy, & Hobbs, 1990) shown in Table 1. Samples were prepared for taste panels as follows: fish were filleted,

Table 1
Sensory evaluation scheme for cooked gilthead sea bream

Score	Odour	Score	Flavour
10	Characteristic	10	Characteristic, lightly sweet
9	Characteristic, less intense	9	Characteristic less intense
8	Characteristic, less intense	8	Characteristic less intense
7	Sweet (lightly)	7	Sweet (lightly)
6	Sweet (but not pleasant)	6	Lightly bitter or acrid or rancid
5	Lightly bitter or acrid or rancid	5	Bitter or acrid or rancid, more intense
4	Acid or acrid or rancid, more intense	4	Bitter or acrid or rancid, intense
3	Acid, ammonia or sulphur (strong)	3	Bitter (strong), ammonia or sulphur

individual fillets were wrapped in an aluminium foil and steam-cooked at 105 °C for 9 min, before being serving to the assessors. Sixteen experienced assessors were selected for this assessment. Data was analysed as described by Laramond (1970). All assessors were trained panellists who frequently consume fish. The panel consisted of six men and 10 women whose age ranged from 23 to 54 years old.

2.6. Statistics

Statistical analysis was performed using Statistica, version 5.0 (Stat. Soft. Inc., Tulsa, OK). Previously, normality and homogeneity of variances were verified by Kolmogorov–Smirnov test. The effect of feeding interruption on proximate chemical composition, lipid profile, amino acids and sensory analysis was analysed by one-way ANOVA followed, where appropriate, by Tukey's post-hoc test, to determine significant differences between the number of days. Percentage data and data which were identified as non-homogeneous through Bartlett's test, were subjected to Kruskal–Wallis test. Differences were regarded as significant when $p < 0.05$.

3. Results and discussion

3.1. Questionnaire on feeding interruption

All aquaculturists used a feeding interruption period; therefore such interruption before capture can be considered a standard practice in the semi-intensive aquaculture systems at Sado's estuary, Portugal. Most of the answers (72%) referred to a feeding interruption period from 2 to 6 days, in order to empty intestines. One day was considered as the minimum period and 8 days was the maximum. Reasons to extend this period beyond 48 h depended on fish market price and the time needed to empty the fishpond.

3.2. Chemical characterisation

The values of moisture, fat, protein and ash contents in anterior and posterior parts are shown in Table 2. Considering two days as a standard period of feeding interruption, the chemical characterization was done on such samples. Thus, on average the fat content (around 13%) was higher than those values reported by Flos et al. (2002) for semi-intensive sea bream and much higher than contents found in wild fish (Table 3). However, it must be considered that in this study the chemical composition refers to skin-on muscle, which would be expected to give a higher fat content than flesh only. Determined protein and ash contents were almost equal to the ones reported in the literature. As a consequence of these results, particularly fat content, data presented in Table 3, which compares different studies on gilthead sea bream chemical composition, suggest that the studied semi-intensive systems were close to intensive rearing. Contrary to what is very often mentioned, fat level in the anterior part of the fish was not higher than that in the posterior part.

Saturated fatty acids (SFA) represented approximately 23% of total fatty acids (Table 4). Palmitic acid (16:0) was the main component, followed by myristic (14:0) and stearic (18:0) acids. Monounsaturated fatty acids (MUFA), accounted for about 42% of the total fatty acids, the main

Table 2
Effect of feeding interruption on proximate composition (%) of gilthead sea bream[a]

Feeding interruption (day)		Moisture (%)	Fat (%)	Protein (%)	Ash (%)
1	A1	65.3 ± 0.13	14.1 ± 0.21	19.9 ± 0.12	1.3 ± 0.00
	B1	64.0 ± 0.06	15.4 ± 0.46	19.4 ± 0.19	1.3 ± 0.06
2	A2	66.5 ± 0.08	12.9 ± 0.05	20.9 ± 0.35	1.3 ± 0.02
	B2	65.3 ± 0.02	13.5 ± 0.33	20.7 ± 0.59	1.2 ± 0.03
7	A7	65.1 ± 0.19	12.9 ± 0.31	20.4 ± 0.24	1.3 ± 0.00
	B7	64.5 ± 0.24	15.0 ± 0.05	19.4 ± 0.37	1.2 ± 0.02
13	A13	61.9 ± 0.26	17.6 ± 0.29	19.0 ± 0.21	1.3 ± 0.04
	B13	64.7 ± 0.11	14.3 ± 0.21	20.0 ± 0.39	1.3 ± 0.06

[a] A and B represents, respectively, the anterior and posterior parts. Values are means ± standard deviation ($n = 3$).

Table 3
Comparison of gilthead sea bream proximate composition (%) presented by different authors[a]

Authors	Rearing	Type	Origin	FI (h)	Weight (g)	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Alasalvar et al. (2001)	–	Cage	Greece	–	375	18.0 ± 1.19	6.53 ± 1.27	74.74 ± 0.54	1.53 ± 0.05
Flos et al. (2002)	Super-intensive	Tank	Spain	0	305.1 ± 31.6	22.90 ± 0.99	3.94 ± 1.80	71.71 ± 2.07	1.46 ± 0.04
	Semi-intensive	Land		24	312.9 ± 14.6	21.28 ± 0.52	2.53 ± 1.21	73.94 ± 1.10	1.41 ± 0.07
	Semi-intensive	Land		24	303.5 ± 34.3	21.09 ± 0.47	5.98 ± 1.76	71.67 ± 1.52	1.26 ± 0.05
	Wild	–		N/a	336.6 ± 20.3	21.16 ± 0.71	0.92 ± 0.42	76.54 ± 1.06	1.39 ± 0.03
Grigorakis et al. (2003a)	Cultured	Cage	Greece	–	318 ± 27	18.10 ± 0.5	10.50 ± 1.2	70.00 ± 0.30	1.24 ± 0.04
	Cultured	Cage		–	311 ± 38	18.10 ± 0.7	9.80 ± 1.35	71.10 ± 2.50	1.36 ± 0.02
Grigorakis et al. (2003b)	Wild	–	Greece	N/a	400	20.05 ± 2.32	1.16 ± 1.03	78.11 ± 1.79	1.44 ± 0.04
	Wild	–		N/a	400	20.23 ± 0.52	3.72 ± 0.91	74.51 ± 0.54	1.42 ± 0.07
	Cultured	–		–	400	18.08 ± 0.71	9.80 ± 1.36	71.20 ± 2.52	1.37 ± 0.08
	Cultured	–		–	400	20.00 ± 0.50	8.93 ± 3.50	69.56 ± 3.20	1.38 ± 0.05
Grigorakis et al. (2002)	Cultured	–	Greece	–	317.9	18.08 ± 0.71	9.80 ± 1.35	71.20 ± 2.52	1.36 ± 0.07
	Wild	–		–	380.1	20.05 ± 2.32	1.16 ± 1.03	78.11 ± 1.79	1.44 ± 0.04
	Cultured	–		–	320.4	17.99 ± 1.19	6.53 ± 1.27	74.74 ± 0.54	1.53 ± 0.05
	Wild	–		–	501.8	19.45 ± 2.11	0.85 ± 0.91	79.91 ± 1.32	1.47 ± 0.02
	Cultured	–		–	285.0	18.25 ± 0.48	10.37 ± 1.21	69.91 ± 0.32	1.22 ± 0.04
Huidoboro et al. (2001)	–	Land	Spain	48	261.73 ± 27.55	22.31 ± 1.72	5.28 ± 0.87	71.83 ± 0.96	1.27 ± 0.07
Huidoboro and Tejada (2004)	–	Land	Spain	48	308.8 ± 293.73	20.99 ± 2.39	6.20 ± 0.66	71.41 ± 3.10	1.40 ± 0.26
Orban et al. (1996)	Intensive	–	Italy	–	400	19.68 ± 0.83	8.42 ± 2.45	69.07 ± 1.98	1.28 ± 0.10
	Extensive	–		–	400	20.70 ± 0.52	3.78 ± 1.03	73.21 ± 1.54	1.37 ± 0.02
Orban et al. (1998)	Intensive	–	Italy	–	300–350	19.56 ± 0.84	9.46 ± 2.56	68.50 ± 2.59	1.34 ± 0.10
	Extensive	–		–	300–350	20.65 ± 0.67	5.84 ± 2.69	71.80 ± 1.42	1.36 ± 0.12

(N/a) not applicable, (–) not mentioned, (FI) feeding interruption.
[a] Values represent the average of determinations.

components being vaccenic acid (18:1ω7), oleic acid (18:1ω9), palmitoleic acid (16:1ω7) and eicosenoic acid (20:1ω9). The presence of the latter compounds may be related to the effect of the composition of the feed on fish fatty acid profile (Alasalvar, Taylor, Zubcov, Shahidi, & Alexis, 2002). Polyunsaturated fatty acids (PUFA) represented approximately 32% of total, and docosahexaenoic acid (22:6ω3, DHA) represented the major part of the PUFA, followed by linoleic acid (18:2ω6) and eicosapentaenoic acid (20:5ω3). The proportion of DHA was higher than that reported by Orban et al. (1998) for extensive aquaculture systems but lower than values reported by Grigorakis, Alexis, Taylor, and Hole (2002) for wild gilthead sea bream. The ω3/ω6 ratio, varying between 2.69 and 2.76, in the posterior (B) and anterior part (A), respectively, was closer to that of wild gilthead sea bream studied by Grigorakis et al. (2002) and higher than that found by Orban et al. (1998) for extensively cultured sea bream. Moreover, it is important to emphasize that low ω3/ω6 ratios are referred to as an indicator for farmed fish, due to the abundance of ω6 compounds (e.g. 18:2ω6) in the feeds (Alasalvar et al., 2002; Tocher, 2003). As with the proximate composition in A and B, the fatty acid profiles in both parts were not distinguishable. The perivisceral fatty acid profile and ω3/ω6 ratio were similar to that found on skin-on muscle (Table 4). The major essential amino acids (EAA) were in order of decreasing magnitude (Table 5), lysine and leucine; of the non-essential amino acids (NEAA) the quantitatively most important were glutamic acid, aspartic acid, arginine and glycine. The favourable ratio of EAA to NEAA, around 0.70, indicates that this species may be considered as a food source of high-quality protein. On the other hand, it is also important to emphasize the similarity between the amino acid profile of these semi-intensive reared sea bream and that of wild sea bream studied by Bandarra et al. (2004).

3.3. Effect of feeding interruption

Table 6 illustrates the weight and length as well as the respective standard deviations for fish harvested at each day. The fish weight was significantly higher on the first day comparing to the second, seventh and thirteenth day. Such difference is due to two main reasons, the first is related to the capture of fish since it was done with a net, hence larger fish were caught in the first operation and smaller fish were caught in the following captures. The second reason is associated with the gut emptying. Indeed, the absence of material in the intestines after 7 and 13 days of feeding interruption was particularly noticeable. Furthermore, for these two interruption periods, a lower amount of perivisceral fat was visually verified than for the feeding interruptions lasting 1 and 2 days. The experimental fish did not show any degree of sexual maturation and all specimens sampled were in the same size range.

Regarding proximate composition (Table 2), some heterogeneity was observed, which probably was due to variation among individuals. Therefore, there was no clear

Table 4
Effect of feeding interruption on lipid profile (% of total fatty acids) of gilthead sea bream[a]

Fatty acid (%)	Feeding interruption (day)											
	1			2			7			13		
	A1	B1	V1	A2	B2	V2	A7	B7	V7	A13	B13	V13
14:0	3.49 ± 0.35	3.91 ± 1.02	4.07 ± 0.32	3.50 ± 0.34	4.21 ± 0.08	3.82 ± 0.63	3.56 ± 0.60	3.22 ± 0.42	4.68 ± 0.47	3.96 ± 0.57	3.30 ± 0.21	3.72 ± 0.39
15:0	0.22 ± 0.03	0.26 ± 0.05	0.33 ± 0.05	0.31 ± 0.02	0.34 ± 0.02	0.28 ± 0.03	0.33 ± 0.03	0.35 ± 0.03	0.32 ± 0.02	0.32 ± 0.01	0.28 ± 0.04	0.33 ± 0.04
16:0	17.54 ± 0.58	18.42 ± 0.55	17.08 ± 0.27	15.50 ± 0.14	15.86 ± 0.08	16.08 ± 0.85	15.49 ± 0.02	16.39 ± 0.62	16.49 ± 0.76	16.20 ± 0.35	16.07 ± 0.39	16.45 ± 0.27
18:0	2.81 ± 0.37	3.06 ± 0.04	3.36 ± 0.05	2.68 ± 0.01	2.72 ± 0.08	3.26 ± 0.10	2.84 ± 0.20	3.03 ± 0.06	3.24 ± 0.10	2.72 ± 0.12	3.04 ± 0.23	3.18 ± 0.08
Saturated	24.21	25.99	25.31	22.53	23.64	23.89	22.73	23.54	25.41	23.83	23.37	24.05
16:1ω7	9.06 ± 0.73	7.65 ± 1.11	8.68 ± 0.19	9.52 ± 0.81	9.83 ± 0.06	8.17 ± 1.32	10.00 ± 0.03	8.62 ± 1.48	8.51 ± 1.35	9.25 ± 1.00	9.31 ± 1.40	8.55 ± 0.75
18:1ω7 + ω9	26.90 ± 0.39	27.52 ± 2.64	26.63 ± 0.47	25.09 ± 0.43	25.85 ± 0.29	27.64 ± 0.81	25.20 ± 0.19	25.20 ± 0.19	26.26 ± 0.81	25.60 ± 0.33	26.30 ± 1.56	26.66 ± 0.56
20:1ω9	3.86 ± 0.21	2.36 ± 0.68	4.21 ± 0.21	3.76 ± 0.12	3.83 ± 0.10	4.67 ± 0.40	3.81 ± 0.21	3.52 ± 0.73	3.25 ± 0.65	4.13 ± 0.33	4.22 ± 0.49	4.18 ± 0.13
22:1ω9	1.61 ± 0.71	1.62 ± 0.77	1.40 ± 0.12	1.70 ± 0.30	2.14 ± 0.18	1.47 ± 0.32	1.82 ± 0.15	1.50 ± 0.59	1.36 ± 0.17	1.97 ± 0.23	1.59 ± 0.07	1.81 ± 0.09
22:1ω11	1.09 ± 0.08	1.56 ± 0.29	1.55 ± 0.13	1.26 ± 0.11	1.02 ± 0.18	1.31 ± 0.15	1.07 ± 0.11	1.48 ± 0.31	1.58 ± 0.19	1.91 ± 1.26	2.10 ± 1.06	1.48 ± 0.07
Monounsaturated	42.91	42.22	42.91	41.99	43.22	43.75	42.87	41.30	42.20	43.66	44.18	43.53
18:2ω6	6.91 ± 0.55	7.64 ± 1.29	7.10 ± 0.11	6.87 ± 0.29	6.72 ± 0.03	7.43 ± 0.36	6.81 ± 0.02	6.98 ± 0.13	7.10 ± 0.16	6.94 ± 0.17	6.59 ± 0.09	7.08 ± 0.15
18:3ω3	1.05 ± 0.04	1.07 ± 0.12	1.19 ± 0.05	0.78 ± 0.67	1.28 ± 0.02	1.29 ± 0.14	1.30 ± 0.02	1.29 ± 0.08	0.76 ± 0.63	1.29 ± 0.04	1.04 ± 0.04	1.24 ± 0.02
18:4ω3	1.04 ± 0.10	1.11 ± 0.18	1.14 ± 0.07	0.88 ± 0.47	1.06 ± 0.03	1.21 ± 0.14	1.12 ± 0.06	1.11 ± 0.13	1.24 ± 0.04	1.08 ± 0.05	1.05 ± 0.01	1.13 ± 0.06
20:4ω6	0.53 ± 0.25	0.53 ± 0.09	0.49 ± 0.03	0.71 ± 0.01	0.60 ± 0.03	0.47 ± 0.03	0.68 ± 0.04	0.66 ± 0.05	0.45 ± 0.10	0.57 ± 0.04	0.69 ± 0.01	0.54 ± 0.03
20:5ω3 (EPA)	5.37 ± 0.30	5.14 ± 0.64	4.77 ± 0.10	5.38 ± 0.12	4.79 ± 0.12	5.04 ± 0.28	5.11 ± 0.03	4.82 ± 0.34	4.89 ± 0.18	4.92 ± 0.08	5.06 ± 0.13	4.57 ± 0.14
22:5ω3	2.66 ± 0.08	1.81 ± 0.78	2.40 ± 0.06	2.53 ± 0.08	2.33 ± 0.02	2.53 ± 0.10	2.42 ± 0.02	2.36 ± 0.08	2.60 ± 0.11	2.31 ± 0.11	2.39 ± 0.17	2.40 ± 0.08
22:6ω3 (DHA)	13.89 ± 0.46	11.86 ± 0.99	10.44 ± 0.26	12.99 ± 0.40	11.64 ± 0.18	11.00 ± 0.57	12.15 ± 0.32	12.28 ± 0.25	10.90 ± 0.44	11.95 ± 0.31	12.54 ± 0.82	10.57 ± 0.28
Polyunsaturated	32.68	30.91	29.56	32.46	30.64	30.81	31.58	31.46	29.94	31.03	31.24	29.70
$\sum\omega$3 series	24.87	22.06	21.09	23.81	22.34	22.18	23.31	23.03	21.54	22.70	23.00	21.10
$\sum\omega$6 series	7.82	8.85	8.47	8.64	8.30	8.63	8.28	8.44	8.39	8.33	8.24	8.60
$\sum\omega$3:$\sum\omega$6	3.18	2.49	2.49	2.76	2.69	2.57	2.82	2.73	2.57	2.73	2.79	2.45
EPA/DHA	0.39	0.43	0.46	0.41	0.41	0.46	0.42	0.39	0.45	0.41	0.40	0.43
Non-identified	0.20	0.88	2.21	3.03	2.50	1.55	2.82	3.70	2.45	1.48	1.21	2.72

[a] Values represent average of three determinations.

Table 5
Effect of feeding interruption on amino acid composition (g/100 g edible part) of gilthead sea bream

Amino acids	Feeding interruption (day)		Bandarra et al. (2004)
	2	13	Wild
Histidine	0.61	0.56	0.50
Isoleucine	0.67	0.66	0.90
Methionine	0.67	0.66	0.50
Threonine	0.76	0.74	0.80
Phenylalanine	0.88	0.88	0.80
Valine	0.97	0.96	1.00
Leucine	1.48	1.43	1.50
Lysine	1.72	1.67	1.80
EAA[a]	7.75	7.54	7.80
Proline	0.97	0.88	0.80
Serine	0.92	0.90	0.70
Alanine	1.05	1.06	1.20
Arginine	1.18	1.15	1.10
Glycine	1.29	1.24	1.00
Aspartic acid	2.02	2.00	1.90
Tyrosine	0.76	0.75	0.70
Glutamic acid	2.75	2.71	2.80
NEAA[b]	10.93	10.68	10.20
EAA/NEAA	0.71	0.71	0.76

[a] EAA – essential amino acids.
[b] NEAA – non-essential amino acids.

Table 6
Effect of feeding interruption on average length (cm) and weight (g) of gilthead sea bream

Feeding interruption (day)	Length (cm)	Weight (g)
1	32.25 ± 1.03	545.03 ± 61.73
2	30.39 ± 1.33	499.72 ± 71.20
7	30.00 ± 1.18	482.04 ± 40.19
13	29.96 ± 0.63	457.74 ± 24.47

trend in the percentage values of the main four components of the fish. This resulted from the short period of feeding interruption and, also, from the culture system (semi-intensive). According to Rasmussen (2001), mobilization of energy resources during fasting is determined by genetic pool, availability of food (quantity and quality), fish density in the tank, water salinity and temperature, which are referred to as conditions that can influence fish feeding behaviour and metabolism in a semi-intensive culture. With regards to fatty acids, data obtained during feeding interruption (Table 4) revealed significant differences only for palmitic acid ($p < 0.05$). For the anterior portion of fish, palmitic acid had the lowest percentage on the seventh day (15.49%) while, for the posterior part, the lowest value was attained on the second day (15.86%). Not significant but still worth mentioning is the variation of docosahexaenoic acid (22:6ω3). For the anterior part samples, DHA decreased with feeding interruption time, whereas in the posterior part samples such behaviour was not observed. Regarding fatty acids in the perivisceral fat, authors were only able to identify significant differences ($p < 0.05$) for eicosenoic acid (20:1ω9) on the seventh day, as can be seen

Table 7
Effect of feeding interruption on sensory quality of cooked gilthead sea bream

	Feeding interruption (day)			
	1	2	7	13
Odour	9.8 ± 0.3	9.3 ± 1.0	8.7 ± 1.2	8.9 ± 0.7
Flavour	9.6 ± 0.2	8.9 ± 0.9	8.5 ± 1.1	8.8 ± 1.0

Odour and flavour for cooked fish score: 10 – absolutely fresh; 3 – completely putrid. Data are mean results for 16 trained panellists.

Table 8
Effect of feeding interruption on colour parameters of gilthead sea bream

Feeding interruption (day)	L^*	a^*	b^*	Chroma
1	66.35 ± 3.18	−0.34 ± 0.32	11.35 ± 1.09	11.36 ± 1.14
2	60.75 ± 0.93	1.11 ± 0.61	12.81 ± 1.58	12.88 ± 1.54
7	68.61 ± 1.15	1.20 ± 0.42	14.56 ± 0.19	14.61 ± 0.19
13	68.25 ± 4.79	0.63 ± 1.11	12.13 ± 3.56	12.19 ± 3.56

in Table 4. As with other constituents, amino acid profile and content did not show any influence of the feeding interruption period (Table 5). Concerning sensory evaluation of raw samples, the affective test did not reveal any significant difference between different periods of feeding interruption. Similarly, panellists could not identify significant differences ($p > 0.05$) in cooked samples (Table 7).

The results obtained for colour parameters (L^*, a^*, b^*, and chroma value) shown in Table 8, also did not show any clear trend regarding the effect of feeding interruption. The present findings indicate that the restricted feeding of gilthead sea bream cultured in semi-intensive rearing plants did not influence significantly its chemical composition, lipid and amino acid profiles, consumer appreciation and colour. Regarding the fatty acid profile, a high level of DHA was maintained. This species seems able to use its energy reserves, namely perivisceral fat, in order to counterbalance the nutrient shortage arising from feeding interruption for up to 13 days. The effect of feeding restriction on gilthead sea bream shelf life shall deserve special attention in future work, since it can effectively influence the shelf-life under refrigerated conditions.

Acknowledgements

Authors would like to acknowledge SAPALSADO, Sociedade Aquícola do Sado, Lda. for providing samples for analysis.

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