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Food Chemistry 70 (2000) 27–32

Food Chemistry

www.elsevier.com/locate/foodchem

Quality characteristics of sharpsnout sea bream (*Diplodus puntazzo*) from different intensive rearing systems

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Received 4 June 1999; received in revised form 2 November 1999; accepted 2 November 1999

Abstract

An experimental investigation was carried out on sharpsnout sea bream (*Diplodus puntazzo*) reared in cage and in tank to evaluate the influence of the different culturing conditions on the nutritional quality of the fish. Fillets from fish of the same genetic origin and size, reared separately in tank and in cage, were analysed for proximate composition, inorganic elements, unsaponifiable lipid fraction compounds, fatty acid profiles of total, neutral and polar lipids and for textural properties. The proximate composition of differently-reared fish did not differ significantly except for the greater lipid content of the tank-reared specimens. High performance liquid chromatography of unsaponifiable lipids showed significantly higher levels of squalene, cholesterol and all-*trans* retinol in tank-reared fish fillets. Gas chromatography of total, neutral and polar lipids showed few differences between the fatty acid profiles of tank- and cage-reared fish. Firmness and amount of expressed liquid were also influenced by the rearing techniques.
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1. Introduction

Fish farming, providing freshwater, brackish and marine fish species, has registered a rapid expansion in the recent decades worldwide. The different rearing techniques developed, intensive, extensive and semi-extensive, have met the increased human demand for seafood. Fish species peculiar to Italian aquaculture, such as sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*), but also less traditionally farmed species, such as the sharpsnout sea bream (*Diplodus puntazzo*), are available to the market all the year round. Farmed seafoods have an advantage over wild-caught fishery products in that they are produced and harvested under controlled conditions. In intensive farming, fish are cultured in confined or sheltered environments, tanks and cages, employing different production and management practices. Therefore, while fish in the wild are subject to considerable changes of the environment, cultured fish, especially those intensively reared in tanks, grow in more stable conditions. Furthermore, by feeding artificial diets, not only can the fish growth rate be controlled but also the flesh composition, in particular its lipid content, may be modified both quantitatively and qualitatively (Mohr, 1987; Orban, Sinesio & Paoletti, 1997).

While compositional and organoleptic differences between wild and reared fish are largely reported in the literature (Børresen, 1992; Nettleton & Exler, 1992), little information is available on the impact of different rearing techniques on the quality attributes of fish products.

The purpose of this study was to evaluate the nutritional quality of sharpsnout sea bream (*Diplodus puntazzo*) reared in different intensive rearing plants. Fish of the same genetic origin and size, reared separately in tank and in cage, were analysed for proximate composition, inorganic elements, unsaponifiable lipid fraction compounds, fatty acid profiles of total lipids (TL), neutral lipids (NL), polar lipids (PL) and textural properties.

2. Materials and methods

2.1. Fish material

Diplodus puntazzo juveniles were obtained by means of a controlled reproduction technique from a commercial

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PII: S0956-7135(99)00112-7

hatchery in Sicily (Trapani). In May 1997 one group ($n = 10{,}056$; initial body weight 16 g) was stocked in an outdoor concrete tank (1,250 m^3) containing seawater. In the same period 100,000 *Diplodus puntazzo* juveniles from the same hatchery (initial body weight 10 g) were transferred and stocked in a floating cage (2,500 m^3) installed along the Tyrrhenian Sea coast near Gaeta (Latina). Fish of both groups were fed on commercial feeds (Trouvit, Hendrix S.p.A, Varese, Italy) based on fish meal, products and by-products of cereal and oleaginous seeds, blood meal and fortified with vitamins (vitamin A, vitamin D_3, α-tocopherol acetate, vitamin C) as declared by the manufacturing company.

After 9 months rearing, in February 1998, fish (about 300 g weight) were caught with a net, immediately covered with ice and transported on the same day to the National Institute of Nutrition, Rome.

2.2. Sample treatment

Upon arrival fish were immediately gutted, beheaded, washed, filleted, individually vacuum-packed and stored at −75°C until analysed. Textural properties were analysed immediately on fresh fillets as described below. On the day of analysis, four fillets from different fishes selected at random, were rapidly thawed under running cold water when still in the sealed bag, skinned, combined and homogenized in a Waring Blendor for 60 s at a low speed using a previously cooled stainless steel cup.

2.3. Reagents and standard solutions

α-Tocopherol (vitamin E), all-*trans* retinol (vitamin A), cholesterol, squalene and pure fatty acid standards were obtained from Sigma Chemical Co. (St. Louis, MO, USA). *Tert*-butyl-hydroquinone (TBHQ) was from Fluka Chemie AG (Buch, Switzerland). Boron trifluoride in methanol was from Aldrich Chemical Co. (Milwaukee, WI, USA). All solvents (Carlo Erba, Milan, Italy) were of analytical or HPLC grade as required.

Working standard solutions of squalene (1 mg ml^{-1}) and cholesterol (2 mg ml^{-1}) were prepared monthly in a chloroform/methanol (2:1, v/v) mixture and stored at +4°C and −18°C, respectively. α-Tocopherol standard solutions in methanol (0.5 mg ml^{-1}) were prepared daily. Stock solutions of all-*trans* retinol were prepared in absolute ethanol and stored in amber vials at −30°C. Working solutions were obtained by diluting appropriate amounts of the stock solution with absolute ethanol and their exact concentrations determined spectrophotometrically using the specific extinction coefficient (Furr, Barna & Olson, 1992).

Standard solutions of mineral salts for ion exchange liquid chromatography (Spectrosol 100 mg kg^{-1} in 0.5% nitric acid) were obtained from BDH (Poole, UK) and injected after dilution (1:50 v/v) in deionized water. The linearity test was carried out in the range 2–20 mg l^{-1}.

2.4. Analytical procedures

Fish homogenate was analysed for moisture, crude protein and ash content according to AOAC methods (Association of Official Analytical Chemists [AOAC], 1980). Non-protein nitrogen was determined after protein precipitation with 20% (w/v) trichloracetic acid. The pH was measured at 20°C on a water:fish homogenate (1:1 w/w). Fish total lipids were extracted by the method of Bligh and Dyer (1959) slightly modified according to Kinsella, Shimp, Mai and Weichrauch (1977). TBHQ dissolved in methanol (1% w/v) was used as antioxidant during the extraction and saponification procedures. For (α-tocopherol and sterols evaluation the sharpsnout sea bream fillet lipid was saponified under nitrogen atmosphere for 15 min at 70°C in ethanolic potassium hydroxide. For vitamin A determination, the fish lipid extract was saponified overnight at room temperature under nitrogen atmosphere in ethanolic potassium hydroxide. Unsaponifiables were recovered with hexane:ethylacetate (9:1 v/v), evaporated to dryness with the aid of a nitrogen stream and dissolved in a suitable amount of solvent to be filtered through 0.45 μm filters before chromatographic injection. All steps during sample extraction and saponification were conducted avoiding any direct exposure to light and oxygen.

Fatty acid profiles were determined in total lipids (TL), neutral lipids (NL) and polar lipids (PL). Lipid fractionation was accomplished by thin layer chromatography on silica gel G plates following the method of Passi, Picardo, De Luca, Nazzaro-Porro, Rossi and Rotilio (1993). The fatty acid composition of TL, NL and PL was obtained after transesterification of the lipid fraction with a 1:1 (v/v) boron trifluoride in methanol (12% w/v)/ methanol solution (Passi et al., 1993). Fatty acid methyl esters were extracted with hexane and quantified by gas chromatography (GC). Fatty acid content is expressed as % of total fatty acids.

Inorganic and trace elements were analysed in pools of four fillets after homogenation and lyophilisation. Sodium, potassium, calcium and magnesium were analysed by ion exchange liquid chromatography with suppressed conductivity. A weighed amount of sample was ashed in a muffle furnace at 500°C for 24 h. Ashes were dissolved with the smallest amount of nitric acid and the resulting solution brought up to 50 ml with bidistilled water. Trace elements were analysed on lyophilised fish fillet homogenates, without any pretreatment, by Instrumental Activation Analysis as described below. Results are the averages of four replicate analyses performed on different pools of fish fillets for each rearing system. The significance of the difference between the

two culturing systems for each parameter considered was evaluated using the Student's *t*-test.

2.5. Instrumental methods

The high performance liquid chromatograph (HPLC) system used in the analysis of fat-soluble vitamins and sterols was a Hewlett–Packard (HP) 1100 Series liquid chromatograph equipped with a G1311A HP quaternary pump and a G1322A HP vacuum solvent delivery degasser module (Hewlett–Packard, Waldbronn, Germany). The system was interfaced with a G1315A HP UV-visible photodiode array detector and data were processed by the HP Chemstation software. The analytical separations were performed using a stainless steel (25 cm×4.6 mm) 5 μm Ultrasphere C18 column (Beckman, Palo Alto, Ca, USA). α-Tocopherol, squalene and cholesterol were separated isocratically using acetonitrile:methanol (75:25, v/v) as mobile phase at a flow rate of 1.6 ml min^{-1}. Runs were monitored at 215 and 293 nm. All-*trans* retinol was eluted in isocratic conditions with a mobile phase consisting of methanol:water (95:5, v/v) at a flow rate of 1.0 ml min^{-1} as described by Aminullah Bhuiyan, Ratnayake and Ackman (1993). The chromatographic runs were monitored at 325 nm. Vitamins and sterols were identified by their retention times and their UV-visible spectra. Peak areas were used to determine α-tocopherol, squalene, cholesterol and all-*trans* retinol concentrations in the samples by reference to standard curves obtained by chromatographing pure substances under identical conditions. To compensate for any day-to-day variations, a set of standards was routinely saponified and run under the same conditions as samples each day of analysis.

A 6890 Hewlett–Packard gas chromatograph with flame ionization detector (FID), equipped with a SPB™ PUFA fused silica capillary column, 30 m×0.25 mm i.d., 0.20 μm film thickness (Supelco Inc., Bellefonte, PA, USA) was used in this study to analyse fatty acid methyl esters. Operating conditions were the following: helium as carrier gas (flow rate 3.6 ml min^{-1}, head pressure 14.9 psi), split ratio 50:1, injection port temperature 200°C, FID temperature 250°C. The oven temperature was programmed at a rate of 10°C min^{-1} from 50 to 180°C, held constant for 1 min and increased to 210°C at a rate of 4°C min^{-1}. The final temperature was maintained for a further 50 min. Injection volume was 2 μl. Peak areas were integrated and calculated by the HP Chemstation software. Fatty acids were identified by comparison of retention times to authentic standards for area percentage normalization. Relative quantities were expressed as weight percentage of total fatty acids in each sample.

A Dionex-Biolc ion system equipped with a Dionex CS12 Ion Pack column and a suppressed conductivity detector (Camberley, UK) was used to analyse inorganic elements (Na, K, Ca, Mg) in fish fillets. Cation separation was accomplished by an isocratic 20 mM methane sulfonic mobile phase at a flow rate of 1 ml min^{-1}. Chromatographic runs lasted 12 min and a baseline separation of all components was achieved (Rey & Pohl, 1993).

For trace element determination, the combined homogenates from four different fish were lyophilized and enclosed in triplicate, without any pretreatment, in pure quartz vials and irradiated in a 1 MW Triga Reactor for about 14 h in a thermal neutron flux of approximately 2.6 10^{-12} n cm^{-2} s^{-1}. The continuous rotation of the irradiation facility ensured a uniform neutron flux to all samples. After cooling, samples were transferred to polyethylene containers and measured by gamma spectrometry using a high purity germanium detector with a relative efficiency of about 20% and a resolution of 1.9 keV at the 1332 keV peak. Gamma spectra analysis was performed using the Omnigam EG&G Ortec computer program.

Flesh texture was evaluated by single and double compression tests using a model 1140 Universal Testing Machine (Instron Ltd, UK). The amount of expressed liquid (cm^2) and firmness at 30% of compression (Newton) were measured by single compression as described previously (Orban et al., 1997). Cohesiveness was measured by double compression as described by Bourne (1978). For each rearing system, four fresh fillets were used and four replicates for single compression and four for double compression test were carried out (crosshead speed: 50 mm min^{-1}; cylindrical compression plate: 5.85 cm in diameter; specimens dimensions: 1.5×2.0×0.95 cm).

3. Results and discussion

3.1. Proximate composition and inorganic elements

The proximate composition and fatty acid profile of the commercial feed administered to fish in tank and in cage during the period preceding marketing are listed in Tables 1 and 2, respectively. The two diets differed slightly in nutrient contents.

Table 1
Proximate composition of commercial feeds for *Diplodus puntazzo* (g kg^{-1})

	Tank	Cage
Moisture	97	87
Protein	450	463
Total lipid	210	210
Ash	72	73
Total carbohydrates	159	155
Crude fibre	12	12

The proximate compositions of *D. puntazzo* fillets from fish reared with the two different systems were similar (Table 3). The only significant difference was in the lipid content, elevated in both types of fish, but comparatively higher in the tank-reared ones ($P \leqslant 0.05$).

The mineral content of sharpsnout sea bream fillets showed a significantly higher content of sodium ($P \leqslant 0.01$) and potassium ($P \leqslant 0.05$) in tank- and cage-reared fish, respectively (Table 3). However, the overall mineral profile of fillets was characterized by a low sodium and high potassium content, a nutritionally important attribute. As regards micronutrients and trace elements, no significant difference was noticed between the two types of fish studied except for a higher iron level in the tank-reared ones.

Table 2
Fatty acid composition of fish diets expressed as % of total fatty acids

Fatty acid	Tank	Cage
14:0	7.50 ± 0.14	7.83 ± 0.11
15:0	0.46 ± 0.02	0.49 ± 0.02
16:0	20.29 ± 0.28	20.48 ± 0.23
17:0	0.50 ± 0.03	0.52 ± 0.05
18:0	4.24 ± 0.06	3.86 ± 0.08
16:1 n-7	8.19 ± 0.19	8.24 ± 0.17
18:1 n-9	13.50 ± 0.26	11.86 ± 0.21
20:1 n-9	0.79 ± 0.05	0.89 ± 0.07
18:2 n-6	8.85 ± 0.10	8.10 ± 0.12
18:3 n-3	1.38 ± 0.03	1.37 ± 0.05
20:2 n-6	0.13 ± 0.02	0.15 ± 0.03
20:4 n-6	0.73 ± 0.04	0.76 ± 0.02
20:5 n-3	14.84 ± 0.21	15.26 ± 0.25
22:5 n-3	1.23 ± 0.10	1.53 ± 0.12
22:6 n-3	7.29 ± 0.32	8.60 ± 0.29
Total saturated	32.99 ± 0.33	33.18 ± 0.38
Total monounsaturated	22.48 ± 0.43	20.99 ± 0.41
Total polyunsaturated	34.45 ± 0.81	35.77 ± 0.87

Table 3
Proximate composition and mineral content of *Diplodus puntazzo* fillets from different rearing systems

	Tank	Cage
g/100 g wet wt		
Moisture	65.4 ± 2.5	67.4 ± 0.9
Protein (N×6.25)	18.6 ± 0.6	18.1 ± 1.1
Non protein nitrogen	0.3 ± 0.0	0.3 ± 0.0
Total lipid	15.0 ± 1.8	12.0 ± 1.2[a]
Ash	1.2 ± 0.1	1.4 ± 0.2
pH	6.4 ± 0.1	6.3 ± 0.1
mg/100 g wet wt		
Sodium	37.0 ± 0.9	28.0 ± 0.7[b]
Potassium	386.0 ± 20.0	424.0 ± 12.9[a]
Calcium	22.0 ± 0.5	23.0 ± 0.5
Magnesium	33.0 ± 0.9	34.0 ± 1.0
μg/100 g wet wt		
Zinc	566.4 ± 23.0	523.0 ± 20.0
Iron	406.8 ± 19.0	270.0 ± 16.0[b]
Selenium	13.7 ± 2.0	13.0 ± 1.5
Mercury	1.6 ± 0.3	2.0 ± 0.2

[a] $P \leqslant 0.05$.
[b] $P \leqslant 0.01$.

3.2. Unsaponifiable lipid fraction

Fillets from fish reared in tank, which have a higher lipid content, contained more cholesterol ($P \leqslant 0.01$), squalene ($P \leqslant 0.05$) and all-*trans* retinol ($P \leqslant 0.01$), on a wet weight basis, than fish reared in cage (Table 4). All-*trans* retinol ($P \leqslant 0.01$) and α-tocopherol ($P \leqslant 0.05$), which are preferentially associated with membrane phospholipids, were higher, on a lipid gram basis, in cage-reared fish.

3.3. Fatty acids

The percentage distribution of fatty acids in total, neutral and polar lipids from differently-reared sharpsnout sea bream are shown in Tables 5–7. Palmitic acid (16:0) and oleic acid (18:1, *n*-9) were the predominant saturated and monounsaturated fatty acids in both fish types while, among polyunsaturated fatty acids, 18:2, 20:5 and 22:6 were prevalent. Such a profile resembles that of the fish feed (Table 2). In particular, the high content of oleic acid (18:1, n-9) in the feed accounts for the prevalence of monounsaturated fatty acids in fish fillet neutral lipids, fraction known to reflect the dietary pool of fatty acids (Table 6). The quantitative and qualitative influence of dietary lipids on the fatty acid composition of fish lipids is widely reported in the literature (Henderson & Tocher, 1987; Jahncke, Hale, Gooch & Hopkins, 1988).

A higher proportion of polyunsaturated and saturated fatty acids, (about 45 and 34% of the total, respectively) was found in the polar lipid fractions than in total lipids of both fish types (Tables 5 and 7). This may be explained by the preferential association of polyunsaturated fatty acids with phospholipids in membrane structures. Moreover, monoenes were lower

Table 4
Unsaponifiable lipid fraction components in fillets of *Diplodus puntazzo* from different rearing systems

	mg/lipid g		mg/100 g wet wt	
	Tank	Cage	Tank	Cage
Cholesterol	5.12 ± 0.79	5.80 ± 0.43	76.80 ± 3.59	69.60 ± 1.58[b]
Squalene	0.12 ± 0.04	0.09 ± 0.01	1.80 ± 0.42	1.08 ± 0.07[a]
All-*trans* retinol (μg)	0.59 ± 0.01	0.69 ± 0.04[b]	8.85 ± 0.16	8.28 ± 0.14[b]
α-tocopherol	0.07 ± 0.02	0.12 ± 0.02[a]	1.05 ± 0.37	1.44 ± 0.39

[a] $P \leqslant 0.05$.
[b] $P \leqslant 0.01$.

Table 5
Fatty acid profiles of total lipids (TL) in fillets of *Diplodus puntazzo* from different rearing systems (% of total fatty acids)

Fatty acid	TL	
	Tank	Cage
14:0	5.26 ± 0.38	5.94 ± 0.01[a]
15:0	0.47 ± 0.05	0.46 ± 0.01
16:0	17.83 ± 0.51	18.72 ± 0.11[a]
17:0	0.56 ± 0.09	0.47 ± 0.16
18:0	2.64 ± 0.05	2.60 ± 0.20
20:0	0.30 ± 0.05	0.22 ± 0.07
16:1 n-7	8.44 ± 0.51	8.91 ± 0.30
18:1 n-9	19.00 ± 0.12	17.60 ± 0.63[a]
18:1 n-7	3.67 ± 0.15	3.29 ± 0.09[a]
20:1 n-9	2.15 ± 0.06	1.99 ± 0.19
22:1 n-11	0.89 ± 0.15	0.85 ± 0.06
22:1 n-9	0.26 ± 0.04	0.24 ± 0.10
18:2 n-6	7.13 ± 0.13	6.79 ± 0.23
18:3 n-3	1.42 ± 0.10	1.35 ± 0.05
18:4 n-3	1.84 ± 0.09	2.00 ± 0.07
20:2 n-6	0.26 ± 0.01	0.24 ± 0.02
20:4 n-6	0.58 ± 0.05	0.60 ± 0.05
20:5 n-3	9.80 ± 0.15	10.24 ± 0.24[a]
22:5 n-3	3.20 ± 0.36	2.80 ± 0.23
22:6 n-3	9.55 ± 0.82	9.68 ± 0.92
Others	4.75	5.01
Total saturated	27.06 ± 0.69	28.41 ± 0.07[a]
Total monounsaturated	34.41 ± 0.41	32.88 ± 1.01
Total polyunsaturated	33.78 ± 1.10	33.67 ± 1.05

[a] $P \leqslant 0.05$ compared to the tank-rearing system.

Table 6
Fatty acid profiles of neutral lipids (NL) in fillets of *Diplodus puntazzo* from different rearing systems (% of total fatty acids)

Fatty acid	NL	
	Tank	Cage
14:0	5.85 ± 0.20	6.31 ± 0.41
15:0	0.48 ± 0.02	0.49 ± 0.04
16:0	16.99 ± 0.29	16.88 ± 0.41
17:0	0.63 ± 0.03	0.62 ± 0.03
18:0	2.29 ± 0.06	2.20 ± 0.09
20:0	0.25 ± 0.06	0.29 ± 0.06
16:1n-7	9.53 ± 0.35	9.70 ± 0.39
18:1 n-9	21.24 ± 0.23	20.16 ± 0.54[a]
18:1 n-7	3.68 ± 0.08	3.24 ± 0.09[b]
20:1 n-9	2.25 ± 0.06	2.31 ± 0.27
22:1 n-11	1.00 ± 0.13	1.18 ± 0.10
22:1 n-9	0.24 ± 0.07	0.24 ± 0.02
18:2 n-6	7.95 ± 0.15	7.98 ± 0.50
18:3 n-3	1.57 ± 0.06	1.49 ± 0.03
18:4 n-3	1.95 ± 0.02	2.14 ± 0.07[b]
20:2 n-6	0.26 ± 0.03	0.21 ± 0.03
20:4 n-6	0.44 ± 0.04	0.46 ± 0.02
20:5 n-3	8.42 ± 0.12	8.74 ± 0.28
22:5 n-3	2.78 ± 0.09	2.71 ± 0.25
22:6 n-3	7.18 ± 0.21	7.61 ± 0.15[a]
Others	5.02	5.04
Total saturated	26.49 ± 0.39	26.79 ± 0.92
Total monounsaturated	37.94 ± 0.01	36.83 ± 0.60[a]
Total polyunsaturated	30.55 ± 0.40	31.34 ± 0.98

[a] $P \leqslant 0.05$.
[b] $P \leqslant 0.01$ compared to the tank rearing system.

Table 7
Fatty acid profiles of polar lipids (PL) in fillets of *Diplodus puntazzo* from different rearing systems (% of total fatty acids)

Fatty acid	PL	
	Tank	Cage
14:0	0.86 ± 0.11	0.79 ± 0.14
15:0	1.08 ± 0.34	0.81 ± 0.20
16:0	25.23 ± 1.88	26.69 ± 1.75
17:0	0.34 ± 0.03	0.33 ± 0.05
18:0	7.12 ± 0.60	6.23 ± 0.28
20:0	n.d.[c]	n.d.
16:1 n-7	1.57 ± 0.21	1.51 ± 0.03
18:1 n-9	9.87 ± 0.77	9.53 ± 0.75
18:1 n-7	3.33 ± 0.15	2.90 ± 0.13[a]
20:1 n-9	n.d.	n.d.
22:1 n-11	n.d.	n.d.
22:1 n-9	n.d.	n.d.
18:2 n-6	4.35 ± 0.37	3.87 ± 0.08
20:2 n-6	1.35 ± 0.10	0.95 ± 0.14[a]
18:3 n-3	n.d.	n.d.
18:4 n-3	n.d.	n.d.
20:4 n-6	2.00 ± 0.20	1.86 ± 0.12
20:5 n-3	15.39 ± 0.27	16.28 ± 0.20[b]
22:5 n-3	3.88 ± 0.44	3.74 ± 0.32
22:6 n-3	18.60 ± 1.78	19.46 ± 2.43
Others	5.03	5.05
Total saturated	34.63 ± 1.19	34.85 ± 1.98
Total monounsaturated	14.77 ± 1.00	13.94 ± 0.67
Total polyunsaturated	45.57 ± 0.83	46.16 ± 2.63

[a] $P \leqslant 0.05$.
[b] $P \leqslant 0.01$ compared to the tank rearing system.
[c] n.d. Not detectable.

in PL than in NL in consideration of their prevalent use as a fuel source after mobilization from triglyceride stores (McClelland, Zwingelstein, Weber & Brichon, 1995). The pattern of polyunsaturated fatty acids in PL, considered a rather stable fraction, did not reflect that of the diet, as also found by others working on different fish species (Bakir, Melton & Wilson, 1993; McClelland et al., 1995).

Some slight but significant differences between the total, neutral and polar lipid fatty acid profiles of differently-reared sharpsnout sea bream were evident. In particular cage-reared fish showed a significantly higher concentration of 14:0 and 16:0 ($P \leqslant 0.05$) in total lipids, compared to tank-reared fish (Table 5). As regards monounsaturated fatty acids, fish reared in cage showed a significantly lower concentration of 18:1 (n-9) and (n-7) in total, neutral and polar lipids. Cage-reared fish were also characterized by a lower concentration of 20:2 (n-6) ($P \leqslant 0.05$) in the polar lipid fraction and a higher concentration of 20:5 (n-3) in total ($P \leqslant 0.05$) and polar ($P \leqslant 0.01$) lipids in comparison with tank-reared fish (Tables 5 and 7). Higher levels of 18:4 (n-3) ($P \leqslant 0.01$) and 22:6 (n-3) ($P \leqslant 0.05$) in the neutral lipid fraction of cage-reared fish were also detected (Table 6).

Such differences may be ascribed to the different environmental conditions and diets of fish in the two

Table 8
Texture parameters of *Diplodus puntazzo* fillets from different rearing systems

	Tank	Cage
Expressed liquid (cm^2)	6.4 ± 2.1	4.7 ± 0.5^a
Firmness (N)	2.2 ± 0.5	4.1 ± 1.0^b
Cohesiveness	0.107 ± 0.026	0.111 ± 0.033

[a] $P \leqslant 0.05$.
[b] $P \leqslant 0.001$ compared to the tank-rearing system.

distinct plants. Particularly, while fish nutrition in tank relied only on the artificial feed administered, fish grown in cage could obtain nutrients also from the natural food resources available.

3.4. Texture

Textural analyses performed on fresh fillets from each culturing system showed that fish grown in cage were characterized by significantly higher values of firmness ($P \leqslant 0.001$) and lower amounts of expressed liquid ($P \leqslant 0.05$) than those reared in tank. No significant difference was detected between cage- and tank-reared fish as regards cohesiveness (Table 8). The texture parameters here considered, related to the product quality and consumers' preference, may reflect the different growing conditions of the fish under examination as well as some characteristics of their components (i.e. lipids, water activity, aggregation of myofibrillar proteins).

4. Conclusions

From the results here reported some conclusions applicable to the rearing systems analysed, under the specific experimental conditions adopted (sampling season, fish size, diet composition, etc.), may be drawn. Fish from both intensive rearing plants were characterized by a high lipid content. However, fish reared in tank appeared to deposit more fat in the muscle tissue than fish reared in cage. The rearing technologies adopted and the different environmental conditions entailed also affected the lipid profile of fish. In particular, total lipids of cage-reared fish showed a significantly higher sum of saturated fatty acids than tank-reared fish ($P \leqslant 0.05$). Lipid fractionation revealed that neutral lipids from fish grown in tank had a significantly higher content of total monounsaturated fatty acids with respect to cage-reared fish ($P \leqslant 0.05$). In fish from both rearing systems, a certain correspondence was found between the fatty acid composition of the feed and that of neutral and, as a consequence, total lipids. Textural properties of fish fillets were also influenced by the rearing techniques, particularly as regards firmness and the amount of expressed liquid.

Acknowledgements

Work supported by the Italian Ministry for Agricultural Policies.

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