ELSEVIER

Food Chemistry 79 (2002) 145–150

Food Chemistry

www.elsevier.com/locate/foodchem

Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*): total lipid content, fatty acid and trace mineral composition

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Received 10 October 2001; received in revised form 3 January 2002; accepted 3 January 2002

Abstract

The proximate, fatty acid and trace mineral compositions in the flesh of cultured and wild sea bass (*Dicentrarchus labrax*) were evaluated. Cultured sea bass contained significantly ($P < 0.05$) higher lipids than its wild counterpart. The lipids of cultured sea bass contained significantly ($P < 0.05$) higher proportions of 14:0, 20:0, 18:1n-9, 20:1n-9, 22:1n-9, 18:2n-6 and 20:3n-6, and lower proportions of 16:0, 18:0, 20:4n-6, 20:5n-3, 22:4n-3, 22:5n-3 and 22:6n-3 fatty acid residues than wild sea bass. The percentages of total saturated and polyenoic fatty acids as well as the n-3/n-6 ratio were higher in the wild than in cultured sea bass, whereas the corresponding total monoenoic content was lower. Fe and Zn were predominant elements among 14 minerals analysed and constituted 78.2 and 81.6% of the total mineral contents in the flesh of cultured and wild sea bass, respectively. Although significant ($P < 0.05$) differences existed between cultured and wild sea bass in Fe, Al, Ti and V contents, no significant ($P > 0.05$) differences were noted in the total content of minerals examined. Thus, cultured and wild sea bass may be differentiated using total lipid content, fatty acid proportions and trace mineral compositions and these differences may be attributed to the constituents of the diet of the fish.

Keywords: Cultured and wild sea bass; Proximate analysis; Fatty acids; Trace minerals

1. Introduction

Sea bass (*Dicentrarchus labrax*) is an economically important cultured fish species in the Mediterranean coastal waters. The market demand and, as a result, the price for fresh sea bass has increased markedly over the past decade due to the desirable aroma and quality attributes of this fish; consequently, its farming is deemed to be a profitable business. Thus, many fish farmers on the Mediterranean coasts have gradually expanded their annual production from 581 metric tonnes in 1985 to 53,307 metric tonnes in 1999 (FAO, 2001). On the other hand, intensive production of sea bass has raised concerns over the quality of cultured fish, in comparison with that of the wild fish. It is, therefore, of great importance to compare the cultured and wild fish in terms of their proximate, fatty acid and trace mineral compositions.

Fish lipids are well known to be rich in long-chain n-3 polyunsaturated fatty acids (LC n-3 PUFA), especially eicosapentaenoic acid (EPA or 20:5n-3) and docosahexaenoic acid (DHA or 22:6n-3). These fatty acids play a vital role in human nutrition, disease prevention and health promotion (Horrocks & Yeo, 1999; Kinsella, 1986, 1987; Lees & Karel, 1990; Simopoulos, 1991; Ulbricht & Southgate, 1991). LC n-3 PUFA cannot be synthesised by humans and must be obtained from the diet. Studies have confirmed that the fatty acid compositions of cultured and wild fish are different and diet has been identified as the main reason for the observed differences (Chen, Chapman, Wei, Portier, & O'Keefe, 1995; Grigorakis, Alexis, Taylor, & Hole, 2002; Jahncke, Hale, Gooch, & Hopkins, 1988; Suzuki, Okazaki, Hayakawa, Wada, & Tamura, 1986; Van Vliet & Katan, 1990).

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0308-8146/02/$ - see front matter
PII: S0308-8146(02)00122-X

Aquatic organisms absorb minerals from the diet and surrounding water and deposit them in their skeletal tissues and organs (Lal, 1989). Fish muscle serves as a good source of essential minerals (Bodsha & Sainsbyry, 1978; Farmer, Ashfield, & Samant, 1979; Lal, 1995). The composition of commercial feed used for cultured fish also influences the mineral composition of the fish. Wide variations have been observed in the reported values of mineral concentrations in the same species of fish; variability in sampling procedures and analytical techniques employed might also influence the results (Lal, 1995).

The objective of this study was to investigate the differences between cultured and wild sea bass in proximate, fatty acid and trace mineral compositions.

2. Materials and methods

2.1. Materials

The common cultured sea bass, *Dicentrarchus labrax*, (average weight and length: 224±44 g and 238±14 mm, respectively) used in this study were cultivated in net cages in a Greek farm and harvested (about 1 year old) in May 2000. The commercial feed (LAKY, Nea Kerasounta, Prevezis, Greece) used contained 46% protein, 20% fat, 17.6% carbohydrate, 1.2% crude fibre, 8% moisture and 7.2% ash. Wild sea bass (average weight and length: 203±127 g and 289±44 mm, respectively) were caught in a lagoon of the Aegean Sea. Time of harvest was the same for both fish; all other factors during capture were not controlled or assessed. Average water temperature for both fish was about 18–19 °C. All chemicals were obtained from Sigma-Aldrich-Fluka Company Ltd. (Fancy Road, Dorset, U.K.), unless otherwise specified.

2.2. Sample preparation

Cultured sea bass were slaughtered by immersion in ice cold water (hypothermia) and dispatched (packed into an insulated polystyrene box with ice) by Air Express to the Food Research Centre, University of Lincoln, UK, within 1 day of harvest. Wild sea bass were caught by net and also dispatched at the same time in a similar manner. Three cultured and three wild sea bass were used for proximate and fatty acid analyses upon arrival, while the rest were filleted and then frozen to −40 °C until used for trace mineral analysis. For mineral analysis, six frozen fillets were dispatched (packed into an insulated polystyrene box with dry ice) by Air Express to the Institute of Zoology, Moldavian Academy of Sciences, Moldova. Samples from two fillets of three fish, for both cultured and wild sea bass, were analysed.

2.3. Proximate analysis

The flesh of cultured and wild sea bass were analysed for proximate composition: moisture by air drying (method 950.46), total fat by acid hydrolysis (method 948.15), protein by Kjeldahl (method 981.10) and ash by direct analysis (method 938.08), according to the AOAC (1990) procedures.

2.4. Fatty acid analysis

Fatty acid analysis was carried out according to Park and Goins (1994). Fatty acids in the flesh of cultured and wild sea bass were analysed using a Perkin-Elmer 8700 gas chromatograph equipped with a split/splitless injector and flame ionisation detector (Perkin-Elmer, Beaconsfield, UK). Separation of fatty acid methyl esters was achieved on a Chrompack WCOT fused silica capillary column (50 m×0.25 mm i.d., 0.20 μm; Chrompack, Middelburg, the Netherlands). The oven temperature was 120 °C for 5 min, programmed to 180 °C at 10 °C/min, then programmed to 220 °C at 20 °C/min, and then held there for 20 min. The injector and detector temperatures were maintained at 220 and 225 °C, respectively. The carrier gas was a high purity helium with a linear flow rate of 1 ml/min and split ratio of 1:50. Fatty acid methyl esters were identified using (1) marine lipid methyl esters as standards (Omegawax test mixture No. 4–8476, Supelco Japan Ltd.) and (2) comparison of semilogarithmic plots of the relative retention time (RRT) against carbon chain lengths of known fatty acids from fish oil using the method of Ackman (1989b).

2.5. Trace mineral analysis

Approximately 1 g of fish flesh was subjected to the wet mineralisation by Kjeldahl method with using a mixture of nitric and sulphuric acids (2:1, w/w), according to Zolotov and Kuzmin (1982). Mineral contents of the digest were determined by flame atomic absorption spectrophotometer using an AA-S3 (Carl Zeiss Ltd., Germany), equipped with an X-ray fluorescent scanning detector using a Spectroscan-5 (LOMO Ltd., Saint Petersburg, Russia). Trace minerals were quantified on the basis of peak areas and comparison with

Table 1
Proximate analysis (%) in the flesh of cultured and wild sea bass[a]

Component	Cultured	Wild
Protein	20.7±1.0	19.2±0.7
Fat	5.2±1.3	1.4±1.3
Moisture	72.2±1.8	75.5±3.6
Ash	1.5±0.1	1.5±0.1

[a] Data are expressed as mean±SD ($n=4$) on a fresh weight basis.

a calibration curve obtained with the corresponding standards.

2.6. Statistical analysis

SigmaStat was used to normalise the data, analysis of variance (ANOVA) performed, and differences in mean values determined using Tukey's procedures of a statistical analysis system (SAS, 1990).

3. Results and discussion

3.1. Proximate analysis

The results of proximate analysis of cultured and wild sea bass are shown in Table 1. The cultured sea bass possessed a considerably higher fat and a lower moisture content than wild sea bass, probably due to high dietary fat level in the feed (20%) and reduced activity of the cultured fish. Protein and ash contents did not differ significantly ($P > 0.05$) between cultured and wild fish.

3.2. Fatty acids

The fatty acid profiles of flesh lipids of cultured and wild sea bass are listed in Table 2. The percentage of total saturated and polyenoic acids was higher in wild compared with cultured sea bass, whereas its total monoenoic content was lower. This is probably due to the high content of monoenoic fatty acids in the feed of the cultured fish. It has been reported that assimilation patterns of dietary fatty acids in fish muscle reflect the content of the dietary lipid sources (Arzel et al., 1994; Chen et al., 1995; Grigorakis et al., 2002; Krajnovic-Ozretic, Najdek, & Ozretic, 1994; Pagliarani, Pirini, Trigari, & Ventrella, 1986; Pirini, Gatta, Testi, Trigari, & Monetti, 2000). The major fatty acids identified in both fish were 16:0 (palmitic), 18:0 (stearic), 18:1n-9 (oleic), 20:5n-3 (eicosapentaenoic acid, EPA) and 22:6n-3 (docosahexaenoic acid, DHA). Cultured sea bass contained significantly ($P<0.05$) higher proportions of 14:0, 20:0, 18:1n-9, 20:1n-9, 22:1n-9, 18:2n-6 and 20:3n-6, and lower proportions of 16:0, 18:0, 20:4n-6, 20:5n-3, 22:4n-3, 22:5n-3 and 22:6n-3 than wild sea bass.

Palmitic acid was the primary saturated fatty acid (SFA), contributing approximately 70% to the total SFA content of the lipids for both cultured and wild sea bass. Similar results for sea bass (Krajnovic-Ozretic et al., 1994) and other fish species have also been reported in the literature (Chanmugam, Boudreau, & Hwang, 1986; Chen et al., 1995; Grün, Shi, Fernando, Clarke, Ellersieck, & Beffa, 1999). The total SFA content of lipids were 29.2% in cultured and 33.4% in wild sea bass. Thus, the remaining fatty acids found in both fish (about 70%) were mono-and polyunsaturated fatty acids (MUFA + PUFA). In general, fish are relatively low in SFA (<30%), except for certain species (Akman, 1989a; Nettleton & Exler, 1992).

Table 2
Fatty acids in the flesh of cultured and wild sea bass (% of total fatty acids[a]

Fatty acid	Cultured	Wild
14:0	3.1±0.2a[b]	1.6±0.8b
15:0	0.6±0.2a	0.9±0.5a
16:0	20.5±0.4a	22.6±0.3b
18:0	4.6±0.1a	8.3±0.6b
20:0	0.4±0.1	nd[c]
Total saturated	**29.2**	**33.4**
16:1 n-7	4.5±0.1a	4.3±0.0a
18:1 n-9	20.9±1.0a	11.1±0.1b
20:1 n-9	4.5±0.2a	1.3±0.1b
22:1 n-9	4.2±0.1a	1.4±0.4b
24:1 n-9	0.5±0.2a	1.3±0.6a
Total monoenoic	**34.6**	**19.4**
Σn-6 series	9.3	11.8
18:2 n-6	5.7±0.1a	3.2±0.3b
20:2 n-6	2.1±0.6a	1.2±0.3a
20:3 n-6	0.4±0.2	nd
20:4 n-6	1.1±0.2a	7.4±0.8b
Σn-3 series	**26.8**	**35.6**
18:3 n-3	1.6±0.2a	1.7±0.3a
20:5 n-3	6.0±0.3a	10.6±0.6b
22:4 n-3	nd	0.6±0.2
22:5 n-3	1.1±0.0a	3.2±0.6b
22:6 n-3	18.1±0.3a	19.5±0.5b
Total polyenoic	**36.1**	**47.4**
Σn-3 : Σn-6	2.88	3.02
EPA : DHA	0.33	0.54

[a] Data are expressed as mean±SD ($n=3$).
[b] Means±SD followed by the same letter, within a row, are not significantly different ($P>0.05$).
[c] Not detected.

Oleic acid was identified as the primary monoenoic fatty acid in both fish and was significantly ($P<0.05$) higher in cultured than in wild fish. The higher amount of oleic acid in cultured sea bass and sea bream has been reported to arise from its dominance in the commercial feed (Grigorakis et al., 2002; Krajnovic-Ozretic et al., 1994; Pagliarani et al., 1986). Among n-6 series of the fatty acids, cultured fish have a higher level of 18:2n-6 (linoleic acid) than wild fish. This fatty acid is present in plant oils used in the feed of cultured fish and is accumulated largely unchanged in the lipids of marine fish due to their reduced capacity for chain elongation and desaturation (Owen, Adron, Middleton, & Cowey, 1975; Yamada, Kobayashi, & Yone, 1980). Thus, the higher amount of linoleic acid in cultured fish is again related to the feed ingredient of cultured fish (Chanmugam et al., 1986; Krajnovic-Ozretic et al., 1994; Morishita, Uno, Araki, & Takahashi, 1989; Serot,

Gandemer, & Demaimay, 1998; Suzuki et al., 1986). Wild sea bass, on the other hand, had higher levels of 20:4n-6 (arachidonic acid, AA), in agreement with findings of other researchers (Grigorakis et al., 2002; Serot et al., 1998; Rueda, Lopez, Martinez, Zamora, Divanach, & Kentouri, 1997). Levels of AA are low in cultured fish since the dietary fish oils used contain minimal amounts of this fatty acid (Sargent, Bell, McEvoy, Tocher, & Estevez, 1999).

Among the n-3 series, both fish were good sources of EPA and DHA. The percentages of EPA and DHA in wild sea bass lipids were significantly ($P<0.05$) higher than those of cultured fish, which is in good agreement with those previously reported for sea bass (Krajnovic-Ozretic et al., 1994) and other fish species (Grigorakis et al., 2002; Morishita et al., 1989; Rueda et al., 1997; Serot et al., 1998).

The ratio of n-3 to n-6 fatty acids was higher in wild than in cultured sea bass, in agreement with the data from other fish species (Chanmugam et al., 1986; Jahncke et al., 1988; Renon, Malandra, Biondi, & Ronchi, 1994; Van Vliet & Katan, 1990), and shows that the marine environment provides an excellent source of n-3 rich foods. Ackman and Takeuchi (1986) have reported that the percentage of n-3 PUFA in cultured marine fish lipids is often lower than that in their wild counterparts because the manufactured feeds usually contain high proportions of lipids rich in SFA and MUFA, but are deficient in n-3 PUFA. The lower proportion of n-3 PUFA in cultured fish may reduce the nutritional quality of their lipid components. However, proper choice of dietary lipid would allow the fatty acid composition of cultured fish to be tailored to address the beneficial health aspects and consumer's demands. Of course, the cost effectiveness of feed formulations is a main factor.

Grün et al. (1999) found significant seasonal differences in the fatty acid compositions of wild and cultured crappie. Table 2 shows that wild sea bass had a higher standard deviation than cultured sea bass, demonstrating the larger variations among the samples examined. This could be due to lack of a uniform diet in the wild sea bass as compared with that of their cultured counterparts.

It has been reported that the type and amount of fatty acids in fish tissues vary mainly with what the fish eat, but other factors may also influence their fatty acid composition. Size or age, reproductive status, geographic location, and season all influence fat content and composition of fish muscle (Ackman, 1989a; Nettleton, 1985; Saito, Yamashiro, Alasalvar, & Konno, 1999).

3.3. Trace minerals

Table 3 shows the trace mineral composition of the flesh of cultured and wild sea bass. Fe and Zn were predominant elements among 14 minerals analysed and constituted 78.2 and 81.6% of the total trace mineral contents in cultured and wild sea bass, respectively. Although significant ($P<0.05$) differences existed between cultured and wild sea bass in Fe, Al, Ti and V contents, no significant ($P>0.05$) differences were noted in the total contents of the minerals examined. A higher Fe content in wild sea bass was presumably related to the dominance of the dark muscles in the body; dark muscles are characterised by higher Fe concentrations than light muscles (Lal, 1995; Morozov & Petuchov, 1986). Minerals have been reported to show significant variations among fish species (Abaychi & Al-Saad, 1988; Cross, Hardy, Jones, & Barber, 1973; El-Faer, Rawdah, Attar, & Arab, 1992; Lal, 1995). Several studies have indicated that the concentration of trace minerals in fish is influenced by a number of factors such as seasonal and biological differences (species, size, dark/white muscle, age, sex and sexual maturity), food source and environment (water chemistry, salinity, temperature and contaminants; Bodsha & Sainsbyry, 1978; Farmer et al., 1979; Lal, 1995).

Trace minerals present in the flesh of cultured and wild sea bass were classified according to their type. Thus, Mn, Fe, Co, Cu, Zn, Ni, Mo and Cr (essential), Al, Ti, V and Ag (non-essential) and Pb and Cd (toxic) were detected. The main functions of essential minerals include skeletal structure, maintenance of colloidal system and regulation of acid-base equilibrium. Minerals also constitute important components of hormones, enzymes and enzyme activators (Khan, Ali, Biaswas, & Hadi, 1987; Kirkpatrick & Coffin, 1974; Lal, 1989, 1995). Toxic elements, such as Hg (not measured in this study), Pb and Cd are present at levels below their

Table 3
Contents of trace minerals (μg/g) in the flesh of cultured and wild sea bass[a]

Element	Cultured	Wild
Manganese (Mn)	7.25±0.41a[b]	6.53±1.15a
Iron (Fe)	51.22±2.83a	63.1±5.86b
Cobalt (Co)	0.90±0.20a	0.92±0.23a
Copper (Cu)	3.87±0.55a	2.96±0.22a
Zinc (Zn)	45.1±5.35a	43.6±3.74a
Lead (Pb)	1.03±0.20a	0.84±0.08a
Aluminium (Al)	5.36±0.57a	6.61±0.47b
Titanium (Ti)	2.01±0.08a	1.59±0.09b
Nickel (Ni)	4.89±1.15a	3.43±0.44a
Molybdenum (Mo)	0.70±0.03a	0.59±0.06a
Vanadium (V)	0.24±0.02a	0.19±0.01b
Cadmium (Cd)	0.27±0.07a	0.17±0.01a
Silver (Ag)	0.09±0.02a	0.07±0.01a
Chromium (Cr)	0.17±0.05a	0.15±0.01a
Total	123±8.55a	131±7.01a

[a] Data are expressed as mean±SD (n=3) on a dry weight basis.
[b] Means±SD followed by the same letter, within a row, are not significantly different ($P>0.05$).

hazard level (Hankin, 1972; Kendrey & Roe, 1969; Skerfving, 1972). The latter toxic minerals have been considered to be detrimental to humans if ingested in concentrations above certain levels (Kirkpatrick & Coffin, 1974).

4. Conclusions

Cultured and wild sea bass may be differentiated using total lipid content, fatty acid proportions and trace mineral compositions and these differences may be attributed to diet constituents of the fish. The total lipid content, the proportion of several fatty acids (14:0, 16:0, 18:0, 20:0, 18:1n-9, 20:1n-9, 22:1n-9, 18:2n-6, 20:3n-6, 20:4n-6, 20:5n-3, 22:4n-3, 22:5n-3 and 22:6n-3) and some minerals (Fe, Al, Ti and V) were found to be significantly ($P < 0.05$) different between the flesh of cultured and wild sea bass. The percentage of total saturated and of polyenoic lipid fatty acids and the n-3/n-6 ratios were higher in wild than in cultured sea bass, whereas the corresponding total monoenoic content was lower. These effects may originate from the feed. Thus, total lipid content, fatty acid proportions and trace mineral compositions of fish very much depend upon the diet consumed.

Acknowledgements

The authors gratefully acknowledge funding from the European Union (an INCO-COPERNICUS Project) for this study.

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