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Proximate composition and mineral contents in aqua cultured sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*) analyzed by ICP-MS

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Abstract

The proximate composition and mineral contents of aqua cultured sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*) of Aegean Sea were investigated. There were significant differences between moisture, fat and ash contents of the two species. Sodium, potassium, calcium, magnesium, manganese, iron, zinc and iodine values for sea bass and sea bream were significantly different ($p < 0.05$).

Keywords: Aqua cultured fish; ICP-MS; Mineral content; Sea bass; Sea bream

1. Introduction

Fish is a major source of animal protein and it also contains vitamins. Fish is widely consumed in many parts of the world by humans because it has high protein content, low saturated fat and also contains omega fatty acids known to support good health. Marine foods are very rich sources of mineral components. The total content of minerals in the raw flesh of marine fish and invertebrates is in the range of 0.6–1.5% wet weight. Mineral components such assodium, potassium, magnesium, calcium, iron, phosphorus and iodine are important for human nutrition (Sikorski, Lolakowska, & Pan, 1990). The contents of Na, K, Ca, Mg and P are up to 1 mg/100 g, whereas those of Fe, Zn and I are less than 1 mg/100 g (Kietzmann, Priebe, Rakou, & Reichstein, 1969). Aquaculture of gilthead sea bass (*Dicentrarchus labrax)* and sea bream (*Sparus aurata*) is of major economic importance in the Mediterranean area. Total fishery production of Turkey is approximately 507,772 tons. Aquaculture production is 44,498 tons, out of which 700 tons is sea bass (*D. labrax*) and 794 tons is sea bream (*S. aurata*). Cultured sea bass and sea bream have an important commercial value both for consumption in Turkey and as an exportation material. These fish have white flesh, mild taste and low fat content. The European sea bass production of EU is approximately 11,897 tons, sea bream production of Mediterranean regions is 8136 tons (FAO, 2003).

The objective of this study is to investigate the mineral composition of aqua cultured sea bass and sea bream.

2. Materials and methods

2.1. Materials

Aqua-cultured fresh sea bass (*D. labrax*) and sea bream (*S. aurata*) were cultivated in net cages in a Turkish fish farm (Aegean Sea) and harvested during the period of June and July 2005. The fish were slaughtered by immersing in ice-cold water (hypothermia) and delivered to the laboratory (whole) within 12 h of harvesting, packed in separate insulated polystyrene boxes with ice. Fish was washed

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once, after landing with running tap water. Gutting was carried out in the fish processing plant manually. The mean and standard deviations of the weight and length of the fish studied were 335 ± 42 g and 33 ± 3.1 cm for sea bass and 285 ± 30 g and 29.3 ± 2.5 cm for sea bream, respectively.

2.2. Proximate composition analysis

Moisture content was determined by drying an accurately weighed sample of minced fish in an oven at 103 ± 2 °C for 3 h (Mattissek, Schnepel, & Steiner, 1992). The ash content was obtained by heating the residue for 3 h at 550 °C (AOAC, 1998a, chap. 35). The protein contents were assayed by the method of AOAC, 1998 (AOAC, 1998b, chap. 35). Total lipids were determined on a 1 g sample of the minced fillets using the acid hydrolysis method of Weilmeier and Regenstein (Weilmeier & Regenstein, 2004). The carbohydrate content of fishes was determined by the Merril and Watt method (Merrill & Watt, 1973). Dodici sea bass and dodici sea bream were used for proximate analyses upon arrival, while the rest were filleted and then frozen to −30 °C until used for mineral analysis. For mineral analysis, the frozen fillets were dispatched (packed into an insulated polystyrene box with ice) to the Istanbul University Central Laboratory of Instrumental Analysis, Istanbul.

2.3. Mineral analyses

The Ethos D (Type Ethos plus 1) microwave lab station purchased from Milestone Inc. (Monroe, CT, USA) was used to digest fish samples prior to metal analysis. Thermo electron X7 inductively coupled plasma mass spectrometry (ICP-MS), model X series, UK, was used to analyze digested samples for total metals. The following elements were measured using the ICP-MS: sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), phosphorus (P), iron (Fe), zinc (Zn), selenium (Se) and iodine (I). For each sample, between 0.3 and 0.5 g of fish muscle (wet weight) was weighed and placed in a Teflon digestion vessel with 7 ml of concentrated (65%) nitric acid (HNO_3) and 1 ml of 30% hydrogen peroxide (H_2O_2). The sample in the vessel containing concentrated nitric acid was then subjected to a microwave program as follows: Step 1: 25–200 °C for 10 min at 1000 W; Step 2: 200 °C for 10 min at 1000 W. Digests were finally made up with deionized water to 25 ml in acid washed standard flasks. The concentrations of sodium, potassium, calcium, magnesium, manganese, phosphorus, iron, zinc, selenium and iodine in the fish digests were measured with the ICP-MS. Calibration standards: sodium 1000 ± 3 μg/ml in 1% HNO_3 Cat. #100052-1, potassium 1000 ± 3 μg/ml in 1% HNO_3 Cat. #100041-1, calcium 1000 ± 3 μg/ml in 2% HNO_3 Cat. #10009-1, magnesium 1000 ± 3 μg/ml in 2% HNO_3 Cat. #100031-1, manganese 1000 ± 3 μg/mL in 2% HNO_3 Cat. #100032-1, phosphorus 1000 ± 3 μg/ml in 0.05% HNO_3 Cat. #100039-1, iron 1000 ± 3 μg/ml in 2% HNO_3 Cat. #100026-1, zinc 1000 ± 3 μg/ml in 2% HNO_3 Cat. #100068-1, selenium 1000 ± 3 μg/ml in 2% HNO_3 Cat. #100049-1, and iodine 1000 ± 3 μg/ml in 0.5% H_2O Cat. #IC-II.M was purchased from High-Purity Standards P.O. Box 41727 Charleston, SC 29423, USA. The standards were appropriately diluted and used to calibrate the ICP-MS before metal determinations in samples (EPA, 1994). ICP-MS operating conditions: Nebulizer gas flow 0.91 l/min, radio frequency (RF) 1200 W, lens voltage 1.6 V, cool gas 13.0 l/min, Auxillary gas 0.70 l/min.

2.4. Statistical analysis

The descriptive statistics (mean, standard deviation, range) and one-way analysis of variance (ANOVA) were conducted using Excel XP software. Significance was established at $p < 0.05$ (Sümbüloğlu & Sümbüloğlu, 2002).

3. Results and discussion

3.1. Proximate analysis

Proximate composition of sea bass and sea bream is shown in Table 1. The concentrations of the constituents in sea bass used in these experiments and their standard deviations show 70.71% moisture, 1.66% ash, 20.35% total protein and 6.10% total fat. These results were as expected, and similar to those reported by Kyrana and Lougovois (2002) for sea bass (76.72% moisture, 1.23% ash, 19.43% protein, and 4.81% fat). Proximate composition values (74.4% water, 1.30% ash, 20.03% protein and 3.90% fat) for sea bream have been reported by Grigorakis, Taylor, and Alexis (2003). Proximate composition of fresh sea bream is shown in Table 1. Huidobro, Pastor, López-Caballero, and Tejada (2001) reported that the chemical composition of sea bream from Spain was 71.83% moisture, 1.27% ash, 22.31% total protein and 5.28% total fat. Proximate composition values (74.74% water, 1.53% ash, 18.80% protein and 6.53% fat) have been reported by Alasalvar et al. (2001) for sea bream. Grigorakis, Alexis, Gialamas, and Nikolopoulou (2004) found summer samples of sea bream to comprise 69.91% water, 1.22% ash, 8.25% protein and 10.37% fat. Proximate composition values (72.22% moisture, 1.57% ash, 21.08% protein and 6.01% fat) have been reported by Tejada and Huidobro (2002) for sea bream. It is known that variations in the chemical composition of marine fishes are closely related to nutrition, living area, fish size, catching season, seasonal

Table 1
Proximate analysis (%) of sea bass and sea bream

Chemical composition (%)	Sea bass	Sea bream
Water	70.71 ± 0.64	63.52 ± 0.18
Ash	1.66 ± 0.03	1.35 ± 0.04
Protein	20.35 ± 0.41	19.81 ± 0.48
Fat	6.10 ± 0.34	15.11 ± 0.08
Carbohydrate	1.18 ± 0.15	0.21 ± 0.14

and sexual variations as well as other environmental conditions (Schormüller, 1968; Ludorff & Meyer, 1973). Table 1 gives the proximate composition of sea bass and sea bream; the moisture, fat, ash and carbohydrate contents of sea bass and sea bream were significantly different ($p < 0.05$). Protein contents of fishes were not significantly different ($p > 0.05$) than those found.

3.2. Mineral analysis

The mineral contents of sea bass and sea bream are given in Table 2. 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 (Belitz & Grosch, 2001).

The Na contents of sea bass and sea bream were found to be 773 mg/kg and 289 mg/kg. The Na content of sea bream, ranging from 280 to 370 mg/kg and of Baltic herring ranging from 452 to 802 mg/kg, was reported by Orban et al. (2000) and Tahvonen et al. (2000). However, this value is higher (for blue whitling 1320 mg/kg, for crab 2668 mg/kg, for hoki 6200 mg/kg and for fish based dishes 2280 mg/kg) than that reported by other authors (Dashti, Al-Awadi, Al-Kandari, Ali, & Al-Otaibi, 2004; Gökoğlu & Yerlikaya, 2003; Gökoğlu, Yerlikaya, & Cengiz, 2004; Martínez-Valverde, Periago, Santaella, & Ros, 2000).

The K contents of sea bass and sea bream were found to be 4597 mg/kg and 3938 mg/kg. This result is similar to the K contents of Baltic Herring (2993–4742 mg/kg), sea bream (3860–4240 mg/kg), blue whitling (3880 mg/kg) and trout (3060 mg/kg) reported by Gökoğlu et al. (2004), Martínez-Valverde et al. (2000), Orban et al. (2000) and Tahvonen et al. (2000).

Ca and P are necessary to maintain an optimal bone development, with more of both minerals being required during childhood and growing stages to prevent rickets and osteomalacia. Calcium and phosphorus contents of sea bass were significantly higher ($p < 0.05$) than those found in sea bream. Ca values of 220–230 mg/kg have been reported by Orban et al. (2000) for sea bream. Tahvonen, Aro, Nurmi, and Kallio (2000) found 44–1158 mg/kg of Ca in Baltic Herring. Martínez-Valverde et al. (2000) found 177 mg/kg of Ca in blue whitling. Ca values of 463–854 mg/kg have been reported by Orban et al. (2007) for European perch. The P value agreed with those reported for rainbow trout (3378 mg/kg) (Gökoğlu et al., 2004) and for European perch (2150–2310 mg/kg) (Orban et al., 2007). Shang-gui, Zhi-ying, Fang, Ping, and Tie (2004) found a Ca content of 337 mg/kg and P content of 692 mg/kg in Bleeker.

Table 2
Mineral content (mg/kg) of sea bass and sea bream

Mineral content (mg/kg)	Sea bass	Sea bream
Sodium (Na)	773 ± 1.8	289 ± 1.6
Potassium (K)	4597 ± 5.5	3938 ± 23.6
Calcium (Ca)	636 ± 18.6	192 ± 2.8
Phosphorus (P)	3736 ± 13.0	3560 ± 45.8
Magnesium (Mg)	326 ± 0.6	222 ± 2.4
Manganese (Mn)	0.547 ± 0.011	6.44 ± 0.03
Iron (Fe)	24.7 ± 1.03	225 ± 1.6
Zinc (Zn)	2.833 ± 0.087	1.081 ± 0.002
Selenium (Se)	0.282 ± 0.014	0.236 ± 0.003
Iodine (I)	323 ± 19.6	507 ± 15.3

Magnesium contents of sea bass were significantly higher ($p < 0.05$) than those found in sea bream; however, manganese values of sea bream were significantly higher ($p < 0.05$) than those found in sea bass. Similar results have been reported by Orban et al. (2007) for European perch (218–271 mg/kg Magnesium). Martınez-Valverde, Santaella, Ros, and Periago (1998) determined the Mg value of fish puree (hake) as 385 mg/kg. Alasalvar, Taylor, Zubcov, Shahidi, and Alexis (2002) reported similar levels of manganese (7.25–6.53 mg/kg) in cultured and wild sea bass. The magnesium content of sea bream 330–340 mg/kg has been reported by Orban et al. (2000). Tahvonen et al. (2000) found in Baltic herring 251–336 mg/kg Mg and 0.30–0.63 mg/kg Mn. The concentration of Manganese was found to be 0.01–0.46 mg/kg in pink salmon, 0.01–0.04 mg/kg in red salmon, 0.08–0.63 mg/kg in tuna, 0.03–1.27 mg/kg in mackerel, 0.19–2.55 mg/kg in sardine, and 0.11–2.38 mg/kg in herring (Ikem & Egiebor, 2005).

Iron has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells, and as an integrated part of important enzyme systems in various tissues. Adequate iron in the diet is very important for decreasing the incidence of anemia, which is considered a major health problem, especially in young children. Iron deficiency occurs when the demand for iron is high, e.g., in growth, high menstrual loss, and pregnancy, and the intake is quantitatively inadequate or contains elements that render the iron unavailable for absorption (Belitz & Grosch, 2001; Cámara, Amaro, Barberá, & Clemente, 2005). Sea foods, especially darker fleshed fish, are reasonably good sources of iron, supplying 1–2 mg/100 g muscle (Kinsella, 1988). Iron contents of sea bream (225 mg/kg) were significantly higher ($p < 0.05$) than those found in sea bass (24.7 mg/kg). Turhan, Üstün, and Altunkaynak (2004) determined iron content of anchovy to be 38.9 mg/kg. Shang-gui et al. (2004) found 6.4 mg/kg Fe in Bleeker.

Zinc is known to be involved in most metabolic pathways in plants, animals and humans (Hambidge, 2000). Zinc deficiency can lead to loss of appetite, growth retardation, skin changes and immunological abnormalities (National Research Council Recommended dietary allowances, 1989). Ikem and Egiebor (2005) found Zn level of 3.47–7.26 mg/kg in pink salmon, 3.06–4.65 mg/kg in red salmon, 0.14–9.87 mg/kg in tuna, 3.01–10.99 mg/kg in mackerel, 6.07–20.63 mg/kg in sardine and 6.88–97.79 mg/kg in herring. The level of Zn was 18.7–30.5 mg/kg in Baltic Herring (Tahvonen et al., 2000). Martínez-Valverde et al. (1998) reported the presence of pure Fe and Zn (4.3 mg/kg and

3.4 mg/kg) in fish hake. Orban et al. (2000), however, reported levels of zinc and iron of 5.66–5.23 mg/kg and 4.07–2.7 mg/kg for sea bream. Alasalvar et al. (2002) reported iron content of 51.22–63.1 mg/kg and zinc content of 45.1–43.6 mg/kg in cultured and wild sea bass. Martínez-Valverde et al. (2000) reported that blue whiting contained 4 mg/kg Fe and 5.3 mg/kg Zn. The levels of Zn and Fe were 69.9 mg/kg and 10.4 mg/kg in blue crab (Gökoğlu & Yerlikaya, 2003). The iron and zinc level of rainbow trout was found to be in the range of 2.10–9.68 mg/kg (Gökoğlu et al., 2004). However, this value is higher (for hoki 60 mg/kg Zn, 14 mg/kg Fe) than that reported by other authors (Jung, Park, Moon, & Kim, 2005).

Selenium plays a protective role in preventing carcinogenesis and other chronic diseases. There is evidence that Se plays the role of an antioxidant in man (Belitz & Grosch, 2001; Önnig, 2000). Selenium values were 0.28 mg/kg and 0.24 mg/kg for sea bass and sea bream samples, respectively. Selenium values showed no significant difference ($p > 0.05$) between the two fish species. This result is similar to the Se content of sea bass (0.227 mg/kg) described by Šatović and Beker (2004). This value was lower than that reported by Önnig (2000) for herring (0.347 mg/kg), mackerel (0.498 mg/kg), turbot (0.473 mg/kg), flounder (0.371 mg/kg) and the value reported by Orban et al. (2000) for sea bream (1.37 mg/kg). Plessi, Bertelli, and Monzani (2001) reported the selenium content of angler fish (0.173 mg/kg), salmon (0.353 mg/kg), redfish (0.247 mg/kg), and porgy (0.286 mg/kg). In the literature, fish-based foods have the highest selenium contents among all food types, with a selenium content of 0.23 mg/kg; 0.40 mg/kg being the average (Amodia-Coccheri, Arnese, Roncioni, & Silvestri, 1995; Dashti et al., 2004).

Iodine is an essential trace element of great importance for human nutrition. The element is an essential part of the thyroid hormones, which in turn are necessary for human growth and development. The best known effect of iodine deficiency is endemic goiter. Goiter, meaning an enlarged thyroid, is visual in the front of the neck, where the thyroid gland lies. Sea water fish and other marine foods are frequently regarded as the most important natural source of dietary iodine, but there is little knowledge about fresh water fish (Belitz & Grosch, 2001; Eckhoff & Maage, 1997). The daily intake of iodine recommended by the National Research Council of the US National Academy of Sciences in 1989 was 40 μg/day for young infants (0–6 months), 50 μg/day for older infants (6–12 months), 60–100 μg/day for children (1–10 years), and 150 μg/day for adolescents and adults (National Research Council Recommended dietary allowances, 1989). Eckhoff and Maage (1997) determined iodine content of barbus (0.008 mg/kg), catfish (0.025 mg/kg), tilapia (0.015 mg/kg), carp (0.03 mg/kg).

It is known that a variation in the mineral composition of marine foods is closely related to seasonal and biological differences (species, size, dark/white muscle, age, sex and sexual maturity), area of catch, processing method, food source and environmental conditions (water chemistry, salinity, temperature and contaminant) (Alasalvar et al., 2002; Rodrigo, Ros, Priago, Lopez, & Ortuno, 1998; Turhan et al., 2004).

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