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Comparison of wild and cultured sea bass (*Dicentrarchus labrax*) quality

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ABSTRACT

Chemical composition, nutritional value and other physico-chemical parameters of sea bass from two different geographical areas (Greece and Spain) and from aquaculture and wild origin were studied. Farmed and wild fish differ in proximate composition, colour, and especially in texture, fatty acids and free amino acids (FAAs) profiles. Flesh of wild fish was firmer, which could be attributed to their lower fat content and higher level of activity. Cultured fish showed a higher content of monounsaturated fatty acids and lower of saturated and polyunsaturated fatty acids (PUFAs). Within the PUFA group, $n-3$ fatty acids were predominant in wild sea bass, while $n-6$ were more abundant in farmed fish. Some FAAs related to the characteristic flavour of fish, such as glutamic acid, aspartic acid, alanine, and glycine were more abundant in cultured sea bass. No differences between fish from both farms were found, due to the similar composition of the feed used.

1. Introduction

In Europe, the demand for fresh sea bass (*Dicentrarchus labrax*) has increased over the past 15 years because of its nutritional value, taste, aroma, and overall quality. For this reason, many farmers on the Mediterranean coast have expanded their annual production; sea bass being one of the main cultured fish species in this area (Kyrana & Lougovois, 2002).

Quality of fish flesh is the result of a complex set of characteristics involving factors such as chemical composition, texture, and colour, among others. These quality parameters are influenced by intrinsic (fish species, size, and sexual maturity) and extrinsic factors (source of nutrients, season, water salinity, temperature, etc.) (Børrensen, 1992). The nutritional value and organoleptic characteristics of fish are especially affected by rearing conditions, so that composition and sensory parameters are expected to be different between wild and farmed fish (Børrensen, 1992). In farmed fish, artificial diets provide a wide range of nutrients, which not only determine fish growth rate but also flesh composition, in particular the lipid content, which may be quantitatively and qualitatively modified (Izquierdo et al., 2003).

Some authors have reported differences in the organoleptic characteristics between farmed and wild fish (Grigorakis, Taylor, & Alexis, 2003). However, in other studies these differences have not been found (Farmer, McConnell, & Kilpatrick, 2000). In general, cultured fish have been reported to have a softer texture and milder flavour than wild fish, which has been related to differences in muscle structure, proximate composition and the aromatic compounds profile (Johnston et al., 2006). In addition, farmed fish have the advantage of being reared and harvested under controlled conditions, so that hazards associated with fish consumption can be more easily controlled. It is of considerable interest for the farming industry and consumers to be aware of the compositional and nutritive differences between wild and cultured fish.

The aim of this work was to study chemical composition, nutritional value and physico-chemical parameters of sea bass (*D. labrax*) from different geographical areas and from aquaculture and wild origin.

2. Materials and methods

2.1. Materials

In this work, 27 sea bass from three different origins (two farmed and one wild) were studied, nine fish from each origin. Two different farms supplied aquacultured fish, one farm was set in eastern coast of Spain (Mediterranean Sea, Spain), and the other in Serifos Island (Egean Sea, Greece). In both cases, farmed specimens were reared in net cages in the sea farms fed commercial diets and harvested with about 24 months old. The composition of the commercial feed used in both farms is shown in Table 1. Wild specimens were captured off the Mediterranean coast of Spain; all other factors during capture were not controlled or assessed. Sampling was performed in June 2006.

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Table 1
Proximate composition and fatty acids profile of the diets used in both farms (Greece (G) and Spain (S)).

	G	S
Proximate composition (g/100 g)		
Moisture	9	9
Lipid	18	14
Protein	46	48
Ash	8	9
Crude fibre	1.5	1.7
Fatty acid composition (g/100 g total fatty acids)		
14:0	5.0	5.2
15:0	0.5	0.4
16:0	16.0	15.3
18:0	5.0	4.7
16:1 $n-7$	5.7	5.3
18:1 $n-9$	17.9	14.9
20:1 $n-9$	3.3	2.2
18:2 $n-6$	11.0	11.5
18:3 $n-3$	2.6	1.4
18:4 $n-3$	1.6	1.6
20:1 $n-9$	3.3	2.2
20:5 $n-3$	7.3	8.3
20:4 $n-6$	0.6	0.9
22:1 $n-9$	3.2	2.9
22:5 $n-3$	0.8	0.4
22:6 $n-3$	9.5	10.1
$\sum n-3$	21.8	21.8
$\sum n-6$	12.1	11.9
$\sum n-3$: $\sum n-6$	1.80	1.83

Fish were slaughtered by immersing in ice-cold water (hypothermia) and delivered to the laboratory (whole) within 72 h of harvesting, packed in separate insulated polystyrene boxes with ice-water slurry.

All chemicals were obtained from Panreac (Barcelona, Spain) and Merck (Darmstadt, Germany), except for fatty acid and amino acid standards, which were supplied by Sigma–Aldrich–Fluka Company Ltd. (St. Louis, MO, USA).

2.2. Analytical methods

2.2.1. Biometric measurements

Upon arrival at the laboratory fish were individually weighted (TW) and measured to determine standard length (SL) and depth or maximum height (H). Length was measured from the tip of the mouth to the end of the upper lobe of the caudal fin (total body length), and height consisted of a vertical measurement of the maximum height of the body excluding the fins. Condition factor (CF) was calculated as $CF = (TW/SL^3) \times 100$.

2.2.2. Proximate composition and mineral content

Moisture, lipid, protein, and ash contents were assayed by AOAC Methods 950.46, 991.36, 928.08, and 920.153, respectively (AOAC, 1997).

For mineral composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn) the ashed samples were dissolved in 1 mL of hydrochloric acid (35% v/v Suprapur®, Merck), filtered with cellulose filter paper (Whatman no. 1, Whatman International Ltd., Maidstone, UK), diluted to an appropriate concentration for each elemental, and finally analysed (except for P) with a Perkin–Elmer AA spectrophotometer mod 3110 (Norwalk, CT, USA). The content of P was analysed by UV–Vis spectrophotometry using a CE 10320 series UV–Vis spectrophotometer (Cecil Instruments Ltd., Cambridge, UK).

2.2.3. pH, water activity (a_w), and water holding capacity (WHC)

Muscle pH was measured in a fish/water (1:10, w/v) homogenate, using a pH-meter (Crison Instruments, SA, Alella, Barcelona, Spain). Water holding capacity of fish muscle was determined by centrifugation at 500*g* for 10 min at 10 °C, as proposed by Gómez-Guillén, Montero, Hurtado, and Borderias (2000). Water activity was assessed on minced samples of fish using an Aqualab® apparatus model CX-2 (Decagon Devices Inc., Pullman, WA, USA).

2.2.4. Total volatile basic nitrogen (TVB-N)

Total volatile basic nitrogen was determined by steam distillation according to the method described by Malle and Tao (1987).

2.2.5. Texture

Texture of farmed and wild sea bass was evaluated by shear force and compression test using a TA-XT2® Texture Analyser (Stable Micro System, Surrey, UK), with a load cell of 250 N, and Texture Exponent 32 v1.0 (Stable Micro Systems) software. All textural measurements were performed using 20 × 20 × 10 mm pieces from the dorsal muscle of the fish fillet. Fish samples were only skinned for the shear test. For the compression study, the texture analyser was equipped with a 7.5 cm diameter flat-ended cylindrical plunger. The plunger was pressed downwards at a constant speed of 1 mm s^{-1} into the sample until reaching 50% of sample height. For shear force test, the instrument was equipped with a HDP/BS Warner–Bratzler test cell (Stable Micro Systems), which sliced the samples perpendicularly to the muscle orientation at a constant speed of 1.0 mm s^{-1}.

2.2.6. Colour determination

Instrumental colour analyses were performed with a Minolta colorimeter CM-3600d (Minolta, Osaka, Japan) using the D_{65} light source and a 10° observer.

2.2.7. Fatty acids analysis

Fatty acids were determined by gas chromatography–mass spectrometry (GC–MS). The extraction of the total lipid was carried out according to the method described by Folch, Less, and Sloane-Stanley (1957). Transmethylation was carried out using methanol/hydrochloric acid/dimethoxypropane (40:4:1.6, v/v/v). The derivatized fatty acid methyl esters (FAMEs) were analysed using a gas chromatograph/mass spectrometer (GC–MS) Finnigan TRACE MS (TermoQuest, Austin, TX, USA), according to the method described by Fuentes, Fernández-Segovia, Escriche, and Serra (2009).

2.2.8. Free amino acids (FAAs) analysis

This analysis was undertaken by HPLC with pre-column derivatization using phenylisothiocyanate (PITC), according to the method described by Bugueño, Escriche, Serra, and Restrepo (1999) and modified by Fuentes et al. (2009).

All analyses described above were performed in triplicate.

2.3. Statistical analysis

Statistical treatment of the data was performed using the Statgraphics Plus version 4.0 (Rockville, MD, USA). One-way analysis of variance (ANOVA) was used to establish significant differences between the tree origins. The method used for comparison was the LSD test (least significant difference) with a significance level of $\alpha = 0.05$. A simple regression analysis was performed in order to find a possible correlation between pH and WHC. The data were fitted by a linear model, $Y = a + bX$, where Y represents the pH and X is the WHC.

3. Results and discussion

3.1. Biometric measurements

Table 2 shows the biometric measurements of wild and farmed sea bass. No differences between farmed fish were found due to the similar composition in the feed supplied. Wild sea bass showed higher weight and length compared to farmed fish; however, no differences were observed in height or condition factor between fish samples.

3.2. Proximate composition and mineral content

Proximate composition and mineral content of sea bass are shown in Table 2. In general, no differences were found between fish farmed in Greece and in Spain. This fact could be directly related to the similar composition of the feeds used in both farms. Moisture and protein contents were higher in wild sea bass, while both farmed groups showed a higher lipid content.

The highest protein content observed in wild fish, in no case differed in more than 4% between the three fish groups, which is in agreement with the results reported by Haard (1992).

Higher fat levels in farmed fish compared to wild fish have also been observed for sea bass (Alasalvar, Taylor, Zubcov, Shahidi, & Alexis, 2002; Orban et al., 2002) and other fish species (Alasalvar et al., 2001; Grigorakis, Alexis, Taylor, & Hole, 2002; Grigorakis et al., 2003; Johnston et al., 2006). This result could be due to a variety of factors including availability and type of food, dietary ingredients (commercial diets are usually high in fat content and also include dietary carbohydrate), and reduced activity of the cultured fish (Alasalvar et al., 2002; Orban et al., 2002).

The origin and feeding system did not have any effect on mineral composition, except for calcium content (Table 2). Farmed sea bass from Greece contained the highest concentration of calcium (0.20 mg g^{-1}). In general, the levels of the minerals analysed in this study concur with other findings (Alasalvar et al., 2002; Orban et al., 2002).

3.3. Physico-chemical parameters of sea bass

Average values of pH, a_w, WHC, and TVB-N are shown in Table 3. Wild fish had a significantly higher pH than cultured fish ($p < 0.001$). This difference has previously been observed in other studies on sea bass (Orban et al., 2002; Periago et al., 2005) and other fish species (Olsson, Seppola, & Olsen, 2007).

No significant differences were found in the values of a_w between samples. These values were similar to those reported by Cakli, Kilinc, Cadun, Dincer, and Tolasa (2007) for fresh sea bass. Water holding capacity in wild sea bass was significantly higher ($p < 0.001$) than in farmed fish. Similar differences in WHC between rearing conditions were observed in cod (Olsson et al., 2007). A simple regression analysis was performed in order to study a possible correlation between pH and WHC. The statistical analysis revealed a dependency between both parameters ($r^2 = 0.991$, $p < 0.001$). This correlation has previously been observed by Børrensen (1992). No significant differences were found in TVB-N content, these values being similar to those reported for fresh sea bass (Cakli et al., 2007; Kyrana & Lougovois, 2002; Özden, İnuğur, & Erkan, 2007).

TVB-N concentration in freshly caught fish is typically between 5 and 20 mg N/100 g flesh, whereas levels of 30–35 mg/100 g flesh are generally considered as the limit of acceptability for iced-stored cold water fish (Huss, 1998). All samples were below this acceptability limit, and therefore suitable for consumption at the time of analysis.

Farmed sea bass were darker than wild fish, regardless of origin, as can be observed by the significant lower L^* values ($p < 0.01$) in the two cultured samples (Table 3). These results could be attributed to the differences found in moisture content. Positive relationships between L^* values and moisture content have been demonstrated for several foodstuffs (Bekhit, Morton, Dawson, & Sedcole, 2009; Hernández et al., 2009). According to Offer et al. (1989), a higher moisture content contributes to the creation of refractive indices within the food matrix leading to a lighter colour. On the other hand, fish colour could also be influenced by other factors such as diet, rearing temperature, storage period, etc. (Cakli et al., 2007; Ginés, Valdimarsdottir, Sveinsdottir, & Thorarensen,

Table 2
Biometric measurements, proximate composition, and mineral concentration in farmed (Greece (G) and Spain (S)) and wild sea bass.

	Farmed			
	G	S	Wild	α
Biometric measurements				
Total weight (g)	396.4 ± 26.8[a]	401.44 ± 26.65[a]	439.39 ± 25.20[b]	**
Length (cm)	29.75 ± 1.70[a]	30.61 ± 6.11[a]	32.08 ± 1.27[b]	**
Height (cm)	7.89 ± 0.33[a]	7.72 ± 0.36[a]	7.87 ± 0.49[a]	ns
Condition factor	1.52 ± 0.20[a]	1.42 ± 0.08[a]	1.35 ± 0.20[a]	ns
Proximate composition (g/100 g)				
Moisture	74.56 ± 0.26[a]	76.70 ± 0.16[b]	77.49 ± 0.23[c]	***
Lipid	4.38 ± 0.72[a]	4.57 ± 0.17[a]	1.04 ± 0.70[b]	***
Protein	19.10 ± 0.33[a]	17.39 ± 1.65[b]	21.61 ± 1.16[c]	***
Ash	1.21 ± 0.02[a]	1.20 ± 0.02[a]	1.26 ± 0.02[a]	ns
Mineral composition				
Macrominerals (mg/g)				
Na	0.25 ± 0.09[a]	0.28 ± 0.14[a]	0.29 ± 0.12[a]	ns
Mg	0.11 ± 0.02[a]	0.08 ± 0.02[a]	0.12 ± 0.02[a]	ns
Ca	0.20 ± 0.01[a]	0.10 ± 0.02[b]	0.11 ± 0.02[b]	***
K	1.73 ± 0.43[a]	1.34 ± 0.22[a]	1.52 ± 0.42[a]	ns
P	0.37 ± 0.05[a]	0.29 ± 0.01[a]	0.37 ± 0.22[a]	ns
Microminerals (μg/g)				
Fe	1.10 ± 0.23[a]	1.73 ± 0.53[a]	1.64 ± 0.56[a]	ns
Cu	0.29 ± 0.07[a]	0.27 ± 0.05[a]	0.24 ± 0.13[a]	ns
Mn	0.08 ± 0.02[a]	0.06 ± 0.02[ab]	0.05 ± 0.01[b]	ns
Zn	2.34 ± 0.47[a]	1.68 ± 0.42[ab]	1.64 ± 0.58[b]	ns

Mean ± SD ($n = 9$) with different letters in the same row are significantly different. Level of significance (α): ***$p < 0.001$; **$p < 0.01$; ns: non-significant.

Table 3
Physico-chemical, colour, and textural parameters in farmed (Greece (G) and Spain (S)) and wild sea bass.

	Farmed			
	G	S	Wild	α
Physico-chemical parameters				
pH	6.15 ± 0.03[a]	6.12 ± 0.01[a]	6.36 ± 0.02[b]	***
a_w	0.988 ± 0.002[a]	0.990 ± 0.001[a]	0.990 ± 0.001[a]	ns
WHC (g H_2O held/g H_2O)	0.73 ± 0.03[a]	0.73 ± 0.02[a]	0.84 ± 0.02[b]	***
TVB-N (mg N/100 g)	24.99 ± 1.31[a]	24.19 ± 1.85[a]	23.19 ± 1.44[a]	ns
Colour				
L^*	37.63 ± 4.69[a]	36.66 ± 3.62[a]	42.39 ± 1.54[b]	**
a^*	−2.20 ± 0.81[a]	−2.30 ± 1.75[a]	−3.17 ± 1.03[a]	ns
b^*	2.39 ± 1.41[a]	3.91 ± 1.33[a]	2.66 ± 0.75[a]	ns
Texture				
Compression test				
Firmness (N)	24.51 ± 4.42[a]	22.40 ± 3.48[a]	43.70 ± 1.67[b]	***
Module of deformability (N/s)	9.73 ± 1.39[a]	8.55 ± 1.13[a]	15.21 ± 1.36[b]	**
Shear force test				
$F_{fracture}$ (N)	5.31 ± 0.74[a]	5.62 ± 1.51[a]	25.17 ± 4.80[b]	***
F_{max} (N)	24.91 ± 3.16[a]	24.75 ± 1.82[a]	81.69 ± 0.15[b]	***

Mean ± SD ($n = 9$) with different letters in the same row are significantly different. Level of significance (α): ***$p < 0.001$; **$p < 0.01$; ns: non-significant.

2004). Regarding coordinates a^* and b^*, no significant differences were observed in any case (Table 3).

Results of the instrumental texture analyses (Table 3) show significant differences for all the parameters measured between cultured and wild sea bass, all values being considerably higher in wild specimens, while no differences between the two aquacultured samples were observed. Force required for compressing muscle samples (firmness) was twofold higher in wild than in aquacultured sea bass, these differences being more pronounced in the parameters obtained from the shear test. These results agree with those obtained for other fish species (Farmer et al., 2000; Johnston et al., 2006; Olsson et al., 2007; Periago et al., 2005). This fact could be attributed to a higher fat content and lower levels of activity in farmed fish (Haard, 1992). According to Farmer et al. (2000) activity has been found to affect the softening of the flesh after slaughter. Softening occurred more slowly in fish subjected to additional swimming exercise compared with non-exercised fish. The relationship between texture and fat content has also been observed by different authors (Børrensen, 1992; Ginés et al., 2004; Johnston et al., 2006), who found that an increase in fat content led to a decrease in firmness.

3.4. Fatty acids profile

Fatty acid composition of sea bass is shown in Table 4. The results obtained are similar to those reported for sea bass by other authors (Alasalvar et al., 2002; Pirini, Gatta, Testi, Trigari, & Monetti, 2000), where fatty acid profile was different in wild and farmed fish. No differences were found between aquacultured samples, due to the similar composition in fatty acids of the diets used in both farms (Table 1).

The saturated fatty acids (SAFAs) and polyunsaturated fatty acids (PUFAs) were higher in wild sea bass, whereas farmed specimens showed a higher content of monounsaturated fatty acids (MUFAs). These results agree with those for sea bass and other fish species (Alasalvar et al., 2002; Orban et al., 2002; Periago et al., 2005; Pirini et al., 2000).

Palmitic acid (16:0) was the primary saturated fatty acid in all samples, followed by stearic acid (18:0), these contents being higher in wild fish. Oleic acid (18:1) was identified as the major monounsaturated fatty acid in cultured and wild sea bass. The higher amount of oleic acid in farmed samples could be due to its dominance in the commercial feed (Table 1).

With regard to PUFA, sea bass can be considered as a good source of the $n-3$ series fatty acids, particularly of eicosapentaenoic acid (EPA) and docosahxaenoic acid (DHA), showing the highest levels in wild specimens, which agrees with those of Alasalvar et al. (2001, 2002). In general, the $n-6$ fatty acids, especially linoleic acid, were higher in cultured fish. This fatty acid is present in high proportion in the diets supplied by both farms (Table 1); hence farmed sea bass usually have higher levels of this fatty acid than wild sea bass as it has been reported by Alasalvar et al. (2002) and Periago et al. (2005). In addition, this fatty acid is accumulated largely unchanged in the lipids of marine fish due to their reduced capacity for chain elongation and desaturation. Wild fish showed a significantly higher level of arachidonic acid (20:4) than both aquacultured fish. This difference could be attributed to the low content of arachidonic acid in the diets used in both farms (Table 1).

The ratio of $\sum n-3$:$\sum n-6$ fatty acids was higher in wild (3.27) than in farmed sea bass (Greece: 1.09 and Spain: 1.43), which shows that the marine environment provides a good source of PUFA $n-3$. Therefore, there is a reduction in the nutritional quality in the lipid components of cultured sea bass. The appropriate choice of dietary lipid would allow the fatty acid composition of cultured fish to be tailored to address the beneficial health aspects that consumers expect. The cost of the feed formulations probably is the main factor to be taken into account.

3.5. Free amino acids (FAAs) analysis

Free amino acids profiles of cultured and wild sea bass are listed in Table 5. Cultured sea bass showed higher levels of glutamic acid, glycine, histidine, and alanine, and lower levels of serine, arginine,

Table 4
Fatty acids concentrations in farmed (Greece (G) and Spain (S)) and wild sea bass (g/100 g fatty acids).

	Farmed			
	G	S	Wild	α
Saturated fatty acids (SAFAs)				
14:0	3.35 ± 0.41^a	3.27 ± 0.09^a	2.08 ± 0.07^b	***
15:0	0.73 ± 0.09^a	0.59 ± 0.08^b	0.92 ± 0.04^c	*
16:0	21.50 ± 1.64^a	22.24 ± 0.36^a	24.57 ± 0.96^b	***
17:0	0.29 ± 0.02^a	0.24 ± 0.04^a	0.50 ± 0.14^b	***
18:0	4.51 ± 0.21^a	4.58 ± 0.11^a	9.31 ± 0.34^b	***
Total SAFAs	30.38	30.57	37.38	
Monounsaturated fatty acids (MUFAs)				
16:1 $n-7$	4.19 ± 0.16^a	4.58 ± 0.09^a	5.12 ± 0.56^b	*
18:1 $n-9$	28.27 ± 0.36^a	27.96 ± 0.71^a	16.47 ± 0.42^b	***
20:1 $n-9$	4.01 ± 0.15^a	5.66 ± 1.01^a	1.95 ± 0.10^b	***
Total MUFAs	36.47	36.32	23.54	
Polyunsaturated fatty acids (PUFAs)				
18:2 $n-6$	13.56 ± 1.52^a	9.91 ± 0.35^b	2.73 ± 0.06^c	***
18:3 $n-3$	1.15 ± 0.55^a	1.19 ± 0.31^a	1.13 ± 0.31^a	ns
20:2 $n-6$	1.98 ± 0.48^a	2.10 ± 0.92^a	1.06 ± 0.53^a	ns
20:4 $n-6$	0.33 ± 0.03^a	0.48 ± 0.01^a	5.37 ± 0.30^b	***
20:5 $n-3$ (EPA)	7.81 ± 0.85^a	9.26 ± 0.81^b	12.17 ± 0.13^c	***
22:6 $n-3$ (DHA)	8.33 ± 1.11^a	7.36 ± 0.26^b	16.62 ± 0.81^c	***
Total PUFAs	33.16	30.30	39.08	
$\sum n-3$	17.29	17.81	29.92	
$\sum n-6$	15.87	12.49	9.16	
$\sum n-3$: $\sum n-6$	1.09	1.43	3.27	
EPA:DHA	0.94	1.26	0.73	

Mean ± SD ($n = 9$) with different letters in the same row are significantly different. Level of significance (α): ***$p < 0.001$; *$p < 0.05$; ns: non-significant.

Table 5
Free amino acids concentrations in farmed (Greece (G) and Spain (S)) and wild sea bass (mg/kg flesh).

	Farmed			
	G	S	Wild	α
Aspartic acid	1.03 ± 0.07^a	1.25 ± 0.64^a	1.48 ± 0.31^a	ns
Glutamic acid	24.42 ± 3.25^a	18.58 ± 2.51^a	5.23 ± 0.68^b	***
Asparagine	0.69 ± 0.11^a	1.29 ± 0.91^b	2.78 ± 0.81^c	*
Serine	5.83 ± 1.04^a	4.31 ± 0.98^a	12.88 ± 2.62^b	***
Glycine	44.86 ± 14.49^a	50.01 ± 9.78^a	6.59 ± 1.35^b	***
Histidine	18.45 ± 9.78^a	15.02 ± 2.47^a	2.56 ± 1.23^b	***
Arginine	8.67 ± 7.51^a	9.27 ± 4.63^a	25.74 ± 11.91^b	***
Taurine	168.11 ± 38.27^a	178.51 ± 27.66^a	243.53 ± 47.60^b	***
Threonine	4.23 ± 0.62^a	3.30 ± 0.88^a	2.84 ± 0.54^a	ns
Alanine	18.36 ± 1.53^a	13.58 ± 2.13^a	2.49 ± 0.32^b	***
Proline	2.68 ± 0.49^a	3.58 ± 0.69^a	4.60 ± 0.94^a	ns
Tyrosine	1.80 ± 0.27^a	0.88 ± 0.14^b	0.52 ± 0.29^c	*
Valine	4.02 ± 0.88^a	3.92 ± 0.52^a	3.10 ± 1.38^a	ns
Methionine	3.90 ± 1.57^a	5.50 ± 1.03^a	9.82 ± 1.99^b	***
Isoleucine	23.88 ± 7.21^a	25.36 ± 2.69^a	28.36 ± 4.18^a	ns
Leucine	6.46 ± 2.55^a	6.24 ± 1.36^a	7.64 ± 3.09^a	ns
Phenylalanine	0.65 ± 0.12^a	0.42 ± 0.08^a	1.25 ± 0.23^b	**
Lysine	17.34 ± 4.16^a	16.22 ± 2.68^a	17.88 ± 4.05^a	ns
Total	355.38	357.24	379.29	

Mean ± SD ($n = 9$) with different letters in the same row are significantly different. Level of significance (α): ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; ns: non-significant.

taurine, and methionine than wild sea bass. Wild fish showed the highest pool of FAA (379.29 mg kg^{-1}) compared to cultured fish (Greece: 355.38 mg kg^{-1} and Spain: 357.24 mg kg^{-1}). The differences in the FAA profile could be related to different aspects, such as type of diet, temperature or storage time (Hwang, Chen, Shiau, & Jeng, 2000).

In all samples, taurine was the most abundant FAA, which is in accordance with other studies on fish and molluscs (Fuentes et al., 2009; Sarwar & Botting, 1990). Although taurine has been reported to have no important taste impact or any effect on formation of aroma-active components, it has been recognised to play an important role in human physiological functions (Konosu & Yamaguchi, 1982).

After taurine, the most abundant FAAs were glutamic acid, glycine, histidine, and isoleucine. In addition, arginine, lysine, and leucine appeared in all the samples in higher proportions; these FAAs are considered as the most abundant in aquatic organisms.

Some FAAs are related to the characteristic flavour of fish, such as glutamic acid, aspartic acid, alanine, and glycine (Ruiz-Capillas & Moral, 2004). These amino acids were more abundant in cultured sea bass, except for aspartic acid, for which there were non-significant differences. Different contents in these FAAs could cause variations in fish flavour.

4. Conclusions

Farmed and wild sea bass differ in proximate composition, colour, and especially in texture, fatty acids, and free amino acids profiles. Geographical origin (Spain or Greece) does not affect composition or physico-chemical properties, due to the similar composition of the feed used in both farms. The reduction of PUFA $n-3$ and the increase of MUFA and PUFA $n-6$ in farmed sea bass could imply a loss of nutritional quality of the farmed fish. The differences found in the FAAs related to the characteristic flavour of fish could cause variations in this quality attribute, which could affect fish sensory characteristics perceived by consumers depending on their origin (farmed or wild). For further studies, it would be interesting to carry out a sensory study to check whether the differences observed between wild and cultured sea bass by using instrumental measurements are detected by consumers.

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