Chemical quality and sensory profile of the Mediterranean farmed fish shi drum (Umbrina cirrosa) as affected by its dietary protein/fat levels

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ABSTRACT
Two groups of identically-reared shi drum, having received different diets (Group A: 45% protein and 16% fat and Group B: 48% protein and 12% fat), were compared for their yields and their chemical and sensory quality. They exhibited similar dressing and filleting yields, fat deposit and fillet composition. Differences were observed in the fillet fatty acids, with group B exhibiting higher 16:1\(\alpha-7\), 16:1\(\alpha-9\), 16:0, 18:0, and total saturate contents. Their fillet volatile compounds also differed (group A, in particular, contained higher levels of carbonyl-compounds). A triangle test revealed that the two shi drum groups were perceived as sensory different. A Check-All-That-Apply (CATA) test showed that group A (high dietary lipids) was perceived as having a significantly higher ‘fish oil’ aroma, hardness and elasticity, while group B was characterised mainly by higher ‘sweet taste’, higher ‘hay’ and ‘fresh seaweed’ aroma and ‘crab/prawn’ flavour.

INTRODUCTION

The three representatives of the Sciaenidae family, the meagre (Argyrosomus regius), the brown meagre (Sciaena umbra) and shi drum (Umbrina cirrosa), are among the major farmed fish species proposed for Mediterranean aquaculture diversification (Grigorakis 2015).

The shi drum is an emerging aquaculture species, with a small recorded total production of 45 tonnes in the Mediterranean, with Italy being the main producer of the species (Grigorakis 2015). It possesses desirable quality characteristics and is proposed for various recipes (https://healthyhappylifetips.com/2015/03/01/umbrine-valuable-fish-in-the-mediterranean/).

Studies concerning shi drum farming are sporadic and mainly refer to various aspects of its dietary requirements (Segato et al. 2005a; Akpinar et al. 2012; Henry & Fountoulaki 2014), as a response to fish meal replacement (Segato et al. 2005a), and environmental effects on growth performance (Mylonas et al. 2009). Also, some research on reproduction under aquaculture conditions (Barbaro et al. 2002; Mylonas et al. 2004) and larval rearing (Ayala et al. 2013) has been conducted.

As a satisfactory volume of literature refers to the meagre quality aspects (Poli et al. 2003; Cakli et al. 2006; Piccolo et al. 2008; Grigorakis et al. 2011; Giogios et al. 2013, Martelli et al. 2013; Sinanoglou et al. 2014; García Mesa et al. 2014), the shi drum, being second in terms of production numbers, has received very little attention (Segato et al. 2005a, 2005b, 2007, 2008) and respective data are scarce and limited to a number of somatic indexes and muscle proximate composition.

Dietary protein and fat levels have been shown to have certain effects on fish quality traits in some cases (Nortvedt & Tuene 1998), although impacts are mostly negligible (Segato et al. 2005a; Piccolo et al. 2008; Valente et al. 2011).

The aim of this study was to examine whether and how the shi drum end-product quality and specifically the yields, the chemical and sensory quality, is affected by the diet. For this reason, two shi drum groups, fed either with a high-protein/low-fat diet or with a low-protein/high-fat diet were examined for their quality. The results were expected to provide useful new knowledge on the quality aspects of this species and the ability to tailor its quality using aquaculture management techniques.

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Materials and methods

Two shi drum groups (fish from the same spawn) were reared in sea cages (Dim Mante Bros & Co Aquaculture Farms, Pelasgia Fthiotida, Greece, 38.9 N, 22.9E) under the same farming conditions, but received different extruded diets. Fish of 410 g initial body weight were reared in circular cages (diameter 60 m, depth 19.1 m), 13,000 individuals/cage in triplicate (final density 5.5 kg/m³). The duration of the trial was 4 months (July 2014–October 2014) and water temperature ranged from 24°C to 26°C. Feeding was performed manually, twice a day, to apparent satiation. Growth of the fish was followed by weighing 15% of the population at the beginning of the trial and weighing 10% every month.

Group A received dietary protein at a level of 450 g kg⁻¹ and fat 160 g kg⁻¹, while group B received a 480/120 diet, respectively. The gross composition and fatty acids profile of the two experimental diets appears in Table 1, while their formulations in Table 2. At the end of the feeding trial, fish were ice-slaughtered according to custom farming slaughter conditions and transferred to Hellenic Centre for Marine Research (HCMR) on ice. For each dietary group, a total of 27 fish were checked for their somatic indexes and yields, while 6 fish were used for the chemical analyses.

Basic somatic indexes and yields were recorded, and included the condition index calculated as: \( CI = \frac{100 \times \text{body weight (g)}}{\text{body length}^3 \text{(cm)}^3} \), and slaughter yield, visceral and peritoneal fat indexes, hepatosomatic and gonadosomatic indexes and filleting yield as percentages of total body weight. Fillet proximate composition was assessed using the AOAC (2005) methodology.

Fillet lipids were extracted from 1 g of white muscle with chloroform:methanol (2:1 v/v), following the Folch et al. (1957) methodology. Subsequently, methyl-esterification of fatty acids took place in an N₂ environment, at 50°C for 16 hours, by the addition of anhydrous methanol–2%H₂SO₄ (Christie 1989). Fatty acid methyl-esters were then separated, identified and quantified by GC-FID using Varian 3300, equipped with a flexible fused silica Megabore column (Length: 30 m, inner diameter: 0.32 mm, film thickness: 1 μm) with a bonded stationary phase of CP-WAX. Identification and quantification of fatty acids was according to the Fountoulaki et al. (2003) procedures.

For fillet volatile compounds extraction, 30 g of fine-chopped fillet sample was homogenised with 60 mL 30% w/v NaCl solution, containing 100 ppm BHT as antioxidant, and subsequently underwent simultaneous steam distillation–extraction (SDE). A Likens–Nickerson apparatus was used for this purpose. The volumes and procedures used for the extraction are detailed in a previous publication (Giogios et al. 2013). The samples were stored at −20°C, in sealed GC vials, until analysis. The GC-MS analysis included an Agilent 7890 GC, equipped with an Agilent 5975C mass selective detector (Agilent Technologies, Santa Clara, CA). An extract aliquot of 2 μL was injected, a splitless mode was selected and volatile compounds were separated on an Agilent HP-5MS capillary column (30 m × 0.25 mm, coated with a 0.25 μm film thickness of 5% phenyl–95% methylsiloxane). The carrier gas was Helium (purity 99.999%) at a flow rate of 1.8 mL/min. The injector and transfer line were heated at 200°C and 300°C, respectively. Thermal programming for separation of peaks, mass spectrometer setup and

| Table 1. Gross composition and fatty acid profile of the feeds fed to shi drum. |
|-----------------|-----------------|-----------------|
|                  | DIET A (450/160) | DIET B (480/120) |
| Gross composition, g kg⁻¹ |                        |                        |
| Moisture         | 72.8             | 85.5             |
| Protein          | 448.9            | 478.0            |
| Fat              | 163.4            | 123.6            |
| Ash              | 85.0             | 76.9             |
| NFE              | 302.7            | 321.5            |
| Energy, kJ        | 185.2            | 174.9            |
| P/E, mg kg⁻¹       | 24.24            | 27.32            |
| Fatty acids composition, g kg⁻¹ |                        |                        |
| CI               | 14.0              | 16.0              |
| CI               | 16:0              | 16:0              |
| CI               | 16:1ω-9           | 34.2              |
| CI               | 17:0              | 5.20              |
| CI               | 18:0              | 12.1              |
| CI               | 18:1ω-9           | 400.1             |
| CI               | 18:1ω-7           | 36.2              |
| CI               | 18:2ω-6           | 205.1             |
| CI               | 18:3ω-3           | 18.2              |
| CI               | 20:1ω-9           | 19.2              |
| CI               | 20:2ω-9           | 4.70              |
| CI               | 20:5ω-3           | 42.6              |
| CI               | 22:1ω-9           | 7.90              |
| CI               | 22:2ω-3           | 5.10              |
| CI               | 22:6ω-9           | 42.1              |
| CI               | SFA               | 184.5             |
| CI               | MUFA              | 497.7             |
| CI               | ω3-PUFA           | 108.0             |
| CI               | ω6-PUFA           | 205.2             |

| Table 2. Diet formulations of the two feeds fed to shi drum, g kg⁻¹. |
|-----------------|-----------------|-----------------|
| Raw materials   | DIET A (450/160) | DIET B (480/120) |
| Krill meal      | 27.2             | 27.1             |
| Squid meal      | 27.2             | 27.1             |
| Fish meal       | 326.0            | 340.5            |
| Fish oil        | 122.2            | 81.6             |
| Maize Gluten 60 | 163.0            | 162.3            |
| Premix          | 3.30             | 3.2              |
| Soya HP48, Non GMO | 163.0          | 162.3            |
| Vitamin C-35    | 5.4              | 5.4              |
| Wheat           | 82.3             | 82.3             |
| Wheat Gluten    | 80.5             | 108.2            |
peak identification and quantification procedures are detailed (Giogios et al. 2013). Blank runs between samples ensured the absence of potentially interfering volatile compounds.

The two groups of shi drum were subjected to a triangle test with 15 panellists to examine whether they differ in their overall sensory aspects. Organisation of test and randomisation of samples was according to ISO 4120 (2004). To define further potential differences, the Check All that Apply (CATA) method, with 36 subjects, was employed. The CATA method has been proposed as a quick and simple alternative for gathering sensory information about food products using untrained subjects (Adams et al. 2007). For both tests, panellists were selected among the HCMR personnel on the basis of previous fish product tasting experience, and received no further training prior to the tests. The samples, for both tests, consisted of 3 cm × 2 cm fillet pieces that were steam-cooked for 20 minutes.

Regarding the CATA test, each participant had to select all sensory attributes appropriate for describing the product from a predetermined list of 32 descriptors (Table 3). To include appropriate sensory terms on the CATA test list, a preliminary evaluation of shi drum fillets was conducted by a panel of two experts. During the sensory CATA evaluation, the products were presented in a monadic and randomised order to participants. Regarding the presentation of CATA terms, the order was randomised across all modalities for each of the questionnaires. The two groups of shi drum were statistically checked for their quality differences by a 2-tailed Student’s t-test, while Cochran’s Q-test was used for the statistical interpretation of CATA analysis results (Adams et al. 2007; Dooley et al. 2010).

### Results and discussion

The somatic indexes, yields and fillet proximate composition of the two shi drum groups are presented in Table 4. The two groups did not differ significantly in either of the studied parameters, with the exception of the HSI that was found higher for the group that received the higher fat diet (Group A). Group B also seems to have a tendency for higher average body weight (p = .10), although the groups did not exhibit statistically significant differences.

The shi drum can be characterised as a low-fat species but still appears to accumulate more fillet fat than the meagre (Poli et al. 2003; Piccolo et al. 2008; Grigorakis et al. 2011; Giogios et al. 2013; Sinanoglou et al. 2014; García Mesa et al. 2014). The current fillet proximate composition is within the limits mentioned in the scarce available literature data referring to this species (Segato et al. 2005a, 2005b, 2007, 2008).

An important observation for this species, not previously mentioned in the literature, is that it tends to accumulate its fat around the peritoneum (peritoneal fat) instead of depositing fat in the viscera. Thus, it appears to have low perivisceral fat, as does its relative species, the meagre (Giogios et al. 2013; Grigorakis 2015), but a much higher peritoneal fat index than the meagre or the two major Mediterranean farmed species, the sea bass and the gilthead sea bream (Giogios et al. 2013; Grigorakis 2007).

These findings imply that large quality differences can be observed, even within species of the same family and origin. Our results for fillet fat agree with the only respective data available for the same species, those of Segato et al. (2005a), who also did not find any differentiation in fillet fat with an increase of dietary fat.

The fatty acid composition of the two groups was found to differ, with low-protein/high-fat diet (dietary group A), resulting in lower total saturated fatty acids (SFA) in the fillet and in particularly lower 16:0 and 18:0 contents, as well as lower monounsaturated fatty

### Table 3. Sensory terms (descriptors) that were used for the shi drum Check-all-that-apply (CATA) sensory test.

| Aroma          | Flavour     | Taste   | Texture | Aftertaste |
|----------------|-------------|---------|---------|------------|
| Boiled potato  | Olive oil   | Sweet   | Fatty   | Bitter     |
| Butter         | Metallic    | Salty   | Dry     |            |
| Seaweed/iodine | Fish oil    | Sour    | Hard    |            |
| Fishmeal       | Butter      | Bitter  | Cohesive|            |
| Fish oil       | Hay         | Fibrous |         |            |
| Grass          | Seafood     | Soft    |         |            |
| Cooked shrimp  | Fatty       |         |         |            |
| Olive oil      | Neutral     |         |         |            |
|                | Fish oil    |         |         |            |
|                | Juice       |         |         |            |
|                | Spicy       |         |         |            |

### Table 4. Somatic indexes, yields of shi drum (n = 27) and fillet proximate composition (n = 6) belonging to the two dietary groups.

|                     | Group A       | Group B       |
|---------------------|---------------|---------------|
| Body weight, g      | 575.8 ± 155.6 | 631.1 ± 149.9 |
| Condition index     | 1.44 ± 0.28   | 1.32 ± 0.23   |
| Dressing yield, % body weight | 92.6 ± 4.39 | 92.1 ± 1.52 |
| Visceral fat, % of bw | 0.23 ± 0.20 | 0.24 ± 0.24 |
| Peritoneal fat, % of bw | 0.84 ± 0.46 | 0.90 ± 0.51 |
| Hepatosomatic index (HSI) | 1.43 ± 0.28a | 1.26 ± 0.25a |
| Gonadosomatic index (GSI) | 0.54 ± 0.45 | 0.72 ± 0.80 |
| Filleting yield, % of bw | 32.6 ± 1.50 | 31.5 ± 3.73 |
| Moisture, g kg⁻¹ | 750.0 ± 7.50  | 749.0 ± 8.90  |
| Fat, g kg⁻¹      | 35.1 ± 4.10   | 39.3 ± 5.90   |
| Protein, g kg⁻¹  | 199.0 ± 3.00  | 201.0 ± 1.50  |
| Ash, g kg⁻¹      | 13.3 ± 0.10   | 13.4 ± 0.10   |

Values are given as mean ± standard deviation. Statistically significant differences (p < .05) are denoted by different letters (a,b).
the diets are similar (Table 1).

cate that the dietary fat level can influence the quality of the fillet were detected, out of which 94 were fully identified. The most prominent among them, namely those that exceed a concentration of 1 µg kg\(^{-1}\) fillet tissue, those exceeding their assumed thresholds even at smaller concentrations, or those that were statistically different between the two groups irrespective of their concentration are presented in Table 5. The cumulative concentrations of volatile compound groups are also presented. The high-protein/low-fat diet (Group B) resulted in lower 1-penten-3ol, lower total carbonyls (aldehydes and ketones) in the fish filament (Table 6), as well as individually lower 3-hydroxy-2-butano, hexanal, \textit{trans}-4-heptenal, heptanal, 2-furan-carboxaldehyde. These carbonyls are mainly produced through fatty acid oxidation processes (Josephson et al. 1984; Kawai 1996). This diet (Group B), on the other hand, exhibited higher concentrations of specific hydrocarbons, aliphatic aldehydes of eight or higher carbon atoms (octanal, nonanal, decanal, hexadecanal) and a number of large unsaturated aldehydes (benzaldehyde, 2-E-ocetalen, 2-E-nonenal, 13 octadecenal).

According to the literature, there are cases where different dietary lipid sources resulted in different flavoured volatile compounds in produced fish fillets (Sérot et al. 2001, 2002; Turchini et al. 2004, 2007, 2013; Grigorakis et al. 2009; Moreira et al. 2014). On the other hand, the dietary protein source does not seem to have an effect on fish filament volatile compounds (Silva et al. 2012; Moreira et al. 2014). Our results indicate strongly that, besides the feed lipid sources, the level of dietary fat can also impact on fish filament volatile compounds, even if fillet fat levels do not change (Table 4).

The triangle test showed that the taste panel clearly distinguished between the two groups (9 out of 15 assessors gave the correct answer, \(p < .05\)). Therefore, a CATA test was used to define these differences. The outcome indicated that the high-protein/low-fat diet (group B) was characterised by seaweed/iodine notes, a seafood flavour and sweeter taste, while group A was characterised by higher fish oil aroma and hay flavour, but with a more elastic and hard texture (Table 7). Spicy flavour, fatty flavour and bitter taste were not identified by any of the participants in either of the samples. In the only available data referring to the sensory properties of the shi drum, a dietary fat increase from 17% to 21% resulted in an increase in the intensity of fillet odour (Segato et al. 2008), which in a way agrees with the present results (i.e. there is an apparent odour differentiation, although no overall odour intensity evaluation has been performed). In general, literature concerning the impact of dietary fat and protein levels on the sensory properties of produced fish fillet is scarce. On the contrary, a lot of attention has been given to the effects of fishmeal or fish oil substitution to the fish sensory properties, with attention has been given to the effects of fishmeal or fish oil substitution to the fish sensory properties, with

| Table 5. Fatty acid composition (in g kg\(^{-1}\) fillet) of the two shi drum dietary groups (\(n = 6\)). |
|---------------------------------|-----------------|-----------------|
|                                    | Group A          | Group B          |
| 14:0                              | 0.95 ± 0.14      | 1.07 ± 0.10      |
| 15:0                              | 0.10 ± 0.01      | 0.11 ± 0.01      |
| 16:0                              | 5.59 ± 0.44\(^a\) | 6.75 ± 0.22\(^a\) |
| 16:1o-7                          | 0.10 ± 0.00\(^b\) | 0.14 ± 0.02\(^b\) |
| 16:1o-9                          | 1.29 ± 0.13\(^a\) | 1.56 ± 0.15\(^a\) |
| 16:3o-3                          | 0.14 ± 0.02      | 0.15 ± 0.03      |
| 17:0                              | 0.10 ± 0.01      | 0.11 ± 0.02      |
| 17:1o-9                          | 0.12 ± 0.03      | 0.12 ± 0.01      |
| 18:0                              | 1.26 ± 0.05\(^a\) | 1.45 ± 0.02\(^a\) |
| 18:1o-9                          | 11.01 ± 0.04     | 13.04 ± 1.78     |
| 18:1o-7                          | 1.33 ± 0.21      | 1.19 ± 0.11      |
| 18:2o-6                          | 6.22 ± 0.32      | 7.13 ± 1.00      |
| 18:3o-3                          | 1.09 ± 0.10      | 1.21 ± 0.17      |
| 20:1o-9                          | 0.89 ± 0.11      | 0.94 ± 0.15      |
| 20:2o-9                          | 0.24 ± 0.03      | 0.26 ± 0.04      |
| 20:4o-6                          | 0.31 ± 0.01      | 0.29 ± 0.02      |
| 20:3o-3                          | 0.10 ± 0.01      | 0.07 ± 0.01      |
| 20:4o-3                          | 0.22 ± 0.01      | 0.24 ± 0.02      |
| 20:5o-3                          | 1.33 ± 0.09      | 1.41 ± 0.15      |
| 22:0                              | 0.39 ± 0.04      | 0.39 ± 0.07      |
| 22:1o-9                          | 0.17 ± 0.01      | 0.17 ± 0.02      |
| 22:5o-3                          | 0.68 ± 0.11      | 0.72 ± 0.03      |
| 22:6o-3                          | 2.90 ± 0.23      | 2.66 ± 0.32      |
| SFA                              | 8.40 ± 0.71\(^a\) | 9.88 ± 0.41\(^b\) |
| MUFA                             | 16.3 ± 1.02      | 18.7 ± 2.43      |
| ω3-PUFA                          | 6.48 ± 0.54      | 6.49 ± 0.75      |
| ω6-PUFA                          | 6.54 ± 0.32      | 7.43 ± 1.03      |

Statistically significant differences (\(p < .05\)) are denoted by different letters (a,b).
Table 6. Fillet volatile compounds and volatile compound classes, expressed as µg kg⁻¹ fresh tissue weight, of the two shi drum dietary groups ± standard deviation (n = 6).

| Compound | Rt, min | Charact. Ions, m/z | Group A | Group B |
|----------|---------|--------------------|---------|---------|
| 2-Chloro-2-methyl-Butane | 2.501 | 77,66,55 | 0.98 ± 0.17 | 0.91 ± 0.09 |
| 3-Methyl-2-Butanone | 2.604 | 43,86 | 2.85 ± 0.49b | 2.28 ± 0.17a |
| Propanoic acid | 2.635 | 45,74 | 0.16 ± 0.11b | tr. a |
| 1-Penten-3-ol | 2.708 | 57,41,39 | 0.65 ± 0.07b | 0.47 ± 0.10a |
| 3-Penten-2-ol | 2.744 | 71,43,41 | 0.42 ± 0.10 | 0.35 ± 0.12 |
| 2,3-Pentanedione | 2.903 | 43,57,100 | 0.28 ± 0.04 | 0.21 ± 0.04 |
| 2-Ethyl-furan | 2.836 | 81,53,110 | 0.21 ± 0.05 | 0.18 ± 0.03 |
| cis-2-Pentenal | 3.760 | 55,83,84 | 0.14 ± 0.01 | 0.17 ± 0.08 |
| Toluene | 3.821 | 91,92,65 | 1.09 ± 0.35 | 0.88 ± 0.28 |
| Octane | 4.448 | 43,85,57 | 0.12 ± 0.01 | 0.13 ± 0.02 |
| Hexanal | 4.606 | 44,56,41 | 1.16 ± 0.20b | 0.09 ± 0.11a |
| 3-Pentanol | 4.655 | 59,107,45 | 0.12 ± 0.01 | 0.09 ± 0.01 |
| 2-hexanol | 4.740 | 45,41 | 0.12 ± 0.01 | 0.13 ± 0.01 |
| p-Xylene | 6.522 | 91,106,105 | 1.14 ± 0.06b | 0.84 ± 0.07a |
| o-Xylene | 9.345 | 91,106,105 | 0.02 ± 0.00b | 0.01 ± 0.00b |
| 2-Heptanone | 7.520 | 43,58,71 | 0.09 ± 0.00b | 0.06 ± 0.00a |
| trans-4-heptenal | 7.824 | 41,55,68 | 0.12 ± 0.02b | 0.05 ± 0.00b |
| Heptanal | 7.897 | 70,44,43 | 0.31 ± 0.05b | 0.18 ± 0.01a |
| 1,2,3,4,5-pentamethyl-cyclopentane | 7.544 | 84,57,69 | 0.53 ± 0.18b | 0.25 ± 0.10a |
| 2-Heptanone | 10.014 | 70,43,41 | 0.33 ± 0.11 | 0.32 ± 0.05 |
| 2-Furan-carboxaldehyde | 10.051 | 110,109,53 | 0.53 ± 0.18b | 0.25 ± 0.10a |
| Benzaldehyde | 10.458 | 106,105,77 | 0.14 ± 0.00b | 0.16 ± 0.01b |
| 2,3-octanedione | 12.034 | 43,71,99 | 0.041 ± 0.00a | 0.018 ± 0.00b |
| Octanal | 12.197 | 43,41,57 | 0.16 ± 0.00b | 0.16 ± 0.01b |
| trans,trans-2,4-Heptadienal | 13.394 | 81,110,53 | 0.12 ± 0.02b | 0.07 ± 0.04 |
| Benzeneacetaldehyde | 15.149 | 91,92,120 | 0.39 ± 0.06b | 0.18 ± 0.05a |
| Unknown hydrocarbon | 16.116 | 43,57,71 | tr. a | 0.21 ± 0.00b |
| 2-E-octenal | 16.183 | 41,55,70 | 0.002 ± 0.00b | 0.012 ± 0.00b |
| Nonanal | 19.138 | 57,41,56 | 0.11 ± 0.01b | 0.09 ± 0.01b |
| 2-E-nonenal | 22.705 | 41,43,83 | 0.004 ± 0.00b | 0.010 ± 0.00b |
| 1-Dodecene | 24.834 | 55,41,43 | 0.26 ± 0.10 | 0.22 ± 0.05 |
| 1-Tetradecene | 34.604 | 55,41,43 | 0.23 ± 0.05 | 0.21 ± 0.02 |
| Tetradecane | 36.151 | 57,43,71 | 0.09 ± 0.09 | 0.12 ± 0.10 |
| 2,6 Bis (1,1, dimethylethyl)-cyclohexadiene-1,4dione | 34.945 | 177,220,135 | 0.19 ± 0.07 | 0.11 ± 0.13 |
| Unknwon | 36.539 | 161,203,218 | 1.25 ± 0.27b | 0.26 ± 0.14a |
| Unknwon | 37.701 | 57,135,234 | 0.21 ± 0.12 | 0.15 ± 0.18 |
| Unknwon H/C | 38.723 | 71,43,41 | 0.4± 0.32b | 1.91 ± 0.38b |
| Heptadecane | 40.274 | 57,43,71 | 1.51 ± 0.81b | 2.77 ± 0.49b |
| Octadecane | 41.673 | 57,71,43 | 0.04 ± 0.30 | 0.28 ± 0.19 |
| Hexadecanal | 41.910 | 57,43,82 | 0.08 ± 0.05b | 0.39 ± 0.19b |
| Unknown aldehyde | 42.227 | 69,41,81 | 0.19 ± 0.15 | 0.09 ± 0.10 |
| 9-Nonadecene | 42.671 | 55,83,97 | 0.06 ± 0.01b | 0.14 ± 0.05a |
| Nonadecane | 42.963 | 57,71,43 | 0.13 ± 0.07b | 0.26 ± 0.08b |
| 13 Octadecenal | 44.058 | 55,69,67 | 0.08 ± 0.08b | 0.31 ± 0.12a |
| Unknown aldehyde | 44.307 | 57,82,96 | 0.05 ± 0.08a | 0.27 ± 0.10b |
| Unknown H/C | 45.062 | 57,43,71 | 0.22 ± 0.14 | 0.25 ± 0.07 |
| Unknown H/C | 45.317 | 57,43,71 | 0.26 ± 0.20 | 0.14 ± 0.32 |
| Unknown H/C | 46.771 | 57,43,41 | 0.40 ± 0.11b | 0.18 ± 0.10b |
| Squalene | 46.893 | 69,81,41 | 0.07 ± 0.02b | 0.37 ± 0.11b |

The retention times (Rt) and characteristic ions for each volatile compound are also provided. Statistically significant differences (p < .05) are denoted by different letters (a,b). tr: traces (< 0.01 µg kg⁻¹ fresh weight).
Table 7. Frequency of positive CATA answers, for descriptive terms in which the two shi drum groups differed significantly (p < .05) or showed a tendency for difference (p < .10), along with their level of significance; the CATA test was performed using 36 subjects.

| Descriptive terms                  | Positive answers Group A | Positive answers Group B | Level of significance |
|------------------------------------|--------------------------|--------------------------|-----------------------|
| Seaweed/iodine aroma               | 0                        | 4                        | p = .046              |
| Fish oil aroma                     | 10                       | 2                        | p = .021              |
| Seafood flavour                    | 0                        | 6                        | p = .014              |
| Hay flavour                        | 4                        | 0                        | p = .046              |
| Sweet taste                        | 6                        | 14                       | p = .021              |
| Elastic texture                    | 8                        | 2                        | p = .014              |
| Hard texture                       | 4                        | 0                        | p = .046              |
| Dry texture                        | 20                       | 12                       | p = .074              |
| Bitter aftertaste                  | 8                        | 2                        | p = .014              |

Compliance with ethical standards/requirements

Fish rearing was in compliance with the Federation of Greek Mariculture (FGM) code of conduct/European Code of Conduct with respect to the farmed organism, the environment and the consumer, and Council Directive 98/58/EC. All fish were harvested according to European Food Safety Authority (EFSA) recommended procedures and specifically Food Safety considerations concerning the species-specific welfare aspects of the main systems of stunning and killing of farmed fish (10.2903/j.efsa.2009.1190) and Species-specific welfare aspects of the main systems of stunning and killing of farmed Seabass and Seabream (10.2903/j.efsa.2009.1010).

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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References

Adams J, Williams A, Lancaster B, Foley M. 2007. Advantages and uses of check-all-that-apply response compared to traditional scaling of attributes for salty snacks. Proceedings of the 7th Pangborn sensory science symposium; Minneapolis, MN, USA.

Akpınar Z, Sevgili H, Ozgen T, Demir A, Emre Y. 2012. Dietary protein requirement of juvenile shi drum, Umbrina cirrosa (L.). Aquacult Res. 43:421–429.

AOAC. 2005. Official methods of analysis of AOAC international. Rockville (MD): Association of Official Analytical Chemists.

Ayala MD, Abellán E, Arizcun M, García-Alcázar A, Navarro F, Blanco A, López-Albors OM. 2013. Muscle development and body growth in larvae and early post-larvae of shi drum, Umbrina cirrosa L., reared under different larval photoperiod: muscle structural and ultrastructural study. Fish Physiol Biochem. 39:807–827.

Barbaro A, Francescon A, Bertotto D, Bozzato G, Di Maria I, Patarnello P, Furlan F, Colombo L. 2002. More effective induction of spawning with long-acting Gnrh agonist in the shi drum, Umbrina cirrosa L. (Sciaenidae, Teleostei), a valuable candidate for Mediterranean mariculture. J Appl Ichthyol. 18:192–199.

Cabrall EM, Fernandes TJR, Campos SD, Castro-Cunha M, Oliveira MBPP, Cunha LM, Valente LMP. 3/4/2013. Replacement of fish meal by plant protein sources up to 75% induces good growth performance without affecting flesh quality in ongrowing Senegalese sole. Aquaculture. 380–383:130–138.

Cakli S¸, Dincer T, Cadun A, Saka S¸, Firat K. 2006. Nutrimet content comparison of the new culture species brown meagre (Sciaena umbra). Archiv Fur Lebensmittelhygiene. 57:80–84.

Caprino F, Moretti VM, Bellagamba F, Turchini GM, Busetto ML, Giani I, Paleari MA, Pazzaglia M. 2008. Fatty acid composition and volatile compounds of caviar from farmed white sturgeon (Acipenser transmontanus). Anal Chim Acta. 617:139–147.
Grigorakis K, Fountoulaki E, Giogios I, Alexis MN. 2009. Hern...

Henry M, Fountoulaki E. 2014. Optimal dietary protein/lipid ratio for improved immune status of a newly cultivated Mediterranean fish species, the shi drum (Umbrina cirrosa) fed three pellet sizes and three experimental diets (protein and lipid vegetable oil blends) on the volatile profile of Senegalese sole (Solea senegalensis Kaup, 1858) muscle. Food Chem. 153:327–333.

Mylonas CC, Pavlidis M, Papandroulakis N, Zaiss MM, Tsafarakis D, Papadakis IE, Varsamos S. 2009. Growth performance and osmoregulation in the shi drum (Umbrina cirrosa) adapted to different environmental salinities. Aquaculture. 287:203–210.

Nortvedt R, Tuene S. 1998. Body composition and sensory assessment of three weight groups of Atlantic Halibut (Hippoglossus hippoglossus) fed three pellet sizes and three dietary fat levels. Aquaculture. 161:295–313.

Piccolo G, Bovera F, De Riu N, Marono S, Salati F, Cappuccinelli R, Moniello G. 2008. Effect of two different protein/fat ratios of the diet on meagre (Argyrosomus regius) traits. Ital J Anim Sci. 7:363–371.

Poli BM, Parisi G, Zampacavallo G, Iurzan F, Mecatti M, Lui P, Bonelli A. 2003. Preliminary results on quality and quality changes in reared meagre (Argyrosomus regius): body and fillet traits and freshness changes in refrigerated commercial-size fish. Aquacult Int. 11:301–311.

Reboredo-Rodriguez P, González-Barreiro C, Cancho-Grande B, Simal-Gándara J. 2012. Dynamic headspace/GC–MS to control the aroma fingerprint of extra-virgin olive oil from the same and different olive varieties. Food Control. 25:684–695.

Segato S, Orato A, Fasolato L, Andrighetto I. 2005a. Effect of the partial replacement of fish meal and oil by vegetable products on performance and quality traits of juvenile shi drum (Umbrina cirrosa L.). Ital J Anim Sci. 4:159–166.

Segato S, Fasolato L, Balzan S, Elia CA, Novelli E, Andrighetto I. 2008. Effect of dietary Ee/Nfe ratio on sensorial traits of shi drum. Acta Agric Slovenica. 91:123–127.

Segato S, Fasolato L, Bertotto D, Libertini A, Balzan S, Corato A, Novelli E. 2007. Effect of triploidy on quality traits of shi drum (Umbrina cirrosa L.) until the second rearing year. Aquacult Res. 38:59–65.

Segato S, Lopparelli RM, Borgoni N, Zanella L, Corato A, Andrighetto I. 2005b. Effect of dietary crude fat to Nfe ratio on growth, feed efficiency and quality traits in juvenile shi drum (Umbrina cirrosa). In: Basurco B, Izquierdo M, Montero D, Nengas I, Alexis M, editors. [Mediterranean fish nutrition] Cahiers options Méditerranéennes. Zaragoza: CIHEAM; p. 27–34.
Sérot T, Regost C, Arzel J. 2002. Identification of odour-active compounds in muscle of brown trout (Salmo trutta) as affected by dietary lipid sources. J Sci Food Agric. 82:636–643.

Sérot T, Regost C, Prost C, Robin J, Arzel J. 2001. Effect of dietary lipid sources on odour-active compounds in muscle of turbot (Psetta maxima). J Sci Food Agric. 81:1339–1346.

Silva JMG, Valente LMP, Castro-Cunha M, Bacelar M, Guedes de Pinho P. 2012. Impact of dietary plant protein levels on the volatile composition of Senegalese sole (Solea senegalensis Kaup, 1858) muscle. Food Chem. 131:596–602.

Sinanoglou VJ, Proestos C, Lantzouraki DZ, Calokerinos AC, Miniadis-Meimaroglou S. 2014. Lipid evaluation of farmed and wild meagre (Argyrosomus regius). Eur J Lipid Sci Technol. 116:134–143.

Spurvey S, Pan BS, Shahidi F. 1998. Flavour of shellfish. In: Shahidy F, editor Flavour of meat, meat products, and seafoods. London: Blackie Academic and Professional; p. 159–196.

Turchini GM, Hermon K, Moretti VM, Caprino F, Busetto ML, Bellagamba F, Rankin T, Francis DS. 2013. Seven fish oil substitutes over a rainbow trout grow-out cycle: II) effects on final eating quality and a tentative estimation of feed-related production costs. Aquacult Nutrition. 19:95–109.

Turchini GM, Mentasti T, Caprino F, Panseri S, Moretti VM, Valfrè F. 2004. Effects of dietary lipid sources on flavour volatile compounds of brown trout (Salmo trutta L) fillet. J Appl Ichthyol. 20:71–75.

Turchini GM, Moretti VM, Mentasti T, Orban E, Valfrè F. 2007. Effects of dietary lipid source on fillet chemical composition, flavour volatile compounds and sensory characteristics in the freshwater fish tench (Tinca tinca L.). Food Chem. 102:1144–1155.

Valente LMP, Linares F, Villanueva JLR, Silva JMG, Espe M, Escórcio C, Pires MA, Saavedra MJ, Borges P, Medale F, et al. 2011. Dietary protein source or energy levels have no major impact on growth performance, nutrient utilisation or flesh fatty acids composition of market-sized Senegalese sole. Aquaculture. 318:128–137.