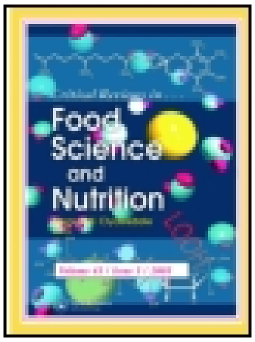

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FILLET PROXIMATE COMPOSITION, LIPID QUALITY, YIELDS AND ORGANOLEPTIC QUALITY OF MEDITERRANEAN FARMED MARINE FISH: A REVIEW WITH EMPHASIS ON NEW SPECIES

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Abstract

Species diversification in Mediterranean mariculture involves various important fish that contribute to the diet of many human populations. These include meagres (Sciaenidae), flatfishes, mullets, and various sparids. Their quality aspects are discussed in this review (yields, fillet proximate composition and lipid quality). Their filleting yield is mostly 40-45%. The viscerosomatic index ranges from 1.5 to 14%, depending on species. Flatfishes' and meagres' low muscle fat contents, differentiate them from the rest of the farmed species. Farmed fish contain high n-3 PUFA (12.3–36.3% vs. 5.48-37.2% in the wild) and have higher muscle fat and n-6 PUFA contents (mainly 18:2n-6) than their wild counterparts. The aquaculture management, diet, and season can affect fillet composition and fatty acids, while season (i.e. food availability and maturation) largely affects lipid quality in wild fish. Data on the sensory quality of Mediterranean farmed species mainly limit to whether specific management differentiates the sensory quality; thus further development of sensory analysis tools is required. Observations on the quality features in farmed Mediterranean fish indicate that species diversification can also provide product diversification, based on different commercial weights and fillet quality specifications.

Keywords

quality, fat, filleting yield, fatty acids, sensory quality

Introduction

The farmed finfish production worldwide was 66.6 million metric tons in 2012 (FAO, 2014). The Mediterranean area is an important contributor to world aquaculture, with two countries, Egypt and Spain being among the top 12 and 20 world aquaculture producers, respectively (FAO, 2013; FAO, 2014). The Mediterranean marine finfish production has been growing, to reach a share of 36% of its total aquaculture output vs. 48% for freshwater fish and 14% for molluscs. Specifically, marine finfish production in the Mediterranean area has grown from 61,024 tons in 1995 to 436,401 tons in 2007 (Barazi-Yeroulanos, 2010). The spark for the continuous growth of the contemporary Mediterranean mariculture was in the late 70s or early 80s. The Mediterranean marine finfish farming all these years has been dominated by two species, the European sea bass (*Dicentrarchus labrax*) and the gilthead sea bream (*Sparus aurata*). These two species are industrially produced and account for approximately 52% of the total marine finfish production in the area (Table 1). The other dominating species, the flathead grey mullet (*Mugil cephalus*), is traditionally semi-intensively farmed in brackish water ponds, and its production is mainly based on wild fry collection (Saleh, 2008). However, there have been some serious fry overfishing issues and recent pressure towards wild fry banning (McGrath, 2012).

In the 90s, the ranching of Atlantic bluefin tuna, *Thunnus thynnus*, was introduced in the area, based on wild stocks capture, since no integrated production could be achieved. The latter has led to almost crashing of the species' stocks in the Mediterranean (MacKenzie et al., 2009). Other sparid species (Table 1) have been farmed with variable success. The market saturation for gilthead sea bream and sea bass and the crisis of this sector during the 90s has led to a persistent recession situation that was enhanced by a general economic crisis (Cardia and Lovatelli, 2007; Perdicaris and Paschos, 2011). Species diversification has been considered a possible way out from this situation (Cardia and Lovatelli, 2007). Among the candidates, various species, mainly from Sciaenidae and Caragidae families, have been proposed and produced nowadays, with meagre (*Argyrosomus regius*) being the most successful one (in terms of production and know-how) (Table 1). Among, the flatfish, the most commercialized in Mediterranean countries, is turbot (*Psetta maxima*), mainly produced in Spain since the 90's. Its farming is integrated and intensive rearing is mostly land-based (FAO 2005-2015).

Regarding their commercial characteristics, these fish species have various commercialization sizes and forms. The grey mullet, besides being sold as whole fish at sizes of about 300-800g, is used for its roe to produce a highly valued traditional product named bottarga (Barra et al., 2008). The Scieanidae species that include the meagre, the brown meagre (*Sciaena umbra*) and the shi drum (*Umbrina cirrosa*) are fast growers that are usually commercialized in sizes bigger than 1 Kg. Although they are usually commercialized as whole, for larger fish various forms like cuts and fillets can be available (Monfort, 2010). Also, small quantities of frozen fish, smoked fillets and sushi sales have been reported for meagre (Monfort 2010). Usual commercialization weights for the various sparid species are similar to those for gilthead sea bream, i.e. 350-500g (Hernández et al., 2001; Barazi-Yeroulanos, 2010) Therefore, they are sold in fresh, whole or gutted forms. The Carangidae family members have large commercialization sizes, and forms similar to the tuna fish, e.g. 3.5-5.5 Kg for greater amberjack (*Seriola dumerili*), sold either in sushi markets or in various cuts (Nakada, 2008). Flatfish, on the other hand, are sold in sizes

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starting from 125g up to 8Kg as whole or fillets, fresh or frozen (Howell, 1997; Imsland et al., 2003).

One significant aspect of the market fate of farmed fish is their quality as perceived by the consumer. Two important aspects in the quality-defining set of parameters, are the nutritional and the technical quality of the fish. The former refers to the nutritional value of the food, while the latter to the processing technical losses and the edible yields. The nutritional significance of fish mainly refers to the contents in polyunsaturated fatty acids and their numerous health benefits (Kris-Etherton et al., 2003; Nicholson et al., 2013). This also reflects to the nutritional status image that the fish has among the consumer (Vanhonacker et al., 2013). The technical quality, on the other side, is mainly an economic aspect and is of interest for both consumers and processors. Furthermore, the organoleptic quality of the fish, i.e. the human sensory impression, is among the capital factors for purchasing those (Grigorakis, 2007).

The aim of this study is to critically review the aforementioned quality aspects for new Mediterranean farmed fish, along with a comparison with their wild counterparts where possible. The importance of examining the quality aspects of these species lies within their universal significance as food, since they are part of the diet, not only in the Mediterranean area but also in many other countries. Besides, they have a great potential for expansion in their production and consumption (Barazi-Yeroulanos, 2010).

Although there is plenty of literature directly comparing farmed and wild-caught gilthead sea bream and sea bass for their quality features (indicatively: Krajnovic-Ozretic et al., 1994; Alasalvar et al., 2002; Grigorakis et al., 2002; Mnari et al., 2007; Periago et al., 2005), there is a scarcity in similar studies for the rest of the Mediterranean fish. Existing data refer only to some of the farmed species and to specific geographic areas (Rueda et al., 1997; Rueda et al., 2001; Cejas et al., 2004; Álvarez et al., 2009; Álvarez et al., 2009b; Dincer et al., 2010). A comparison by reviewing existing literature would elucidate actual differences in quality of farmed and wild Mediterranean fish. Additionally inter-species quality comparisons would allow a better knowledge of how quality differentiates among them and how these individualities could be of commercial advantage. Since there was a similar attempt in the past for gilthead sea bream and sea bass (Grigorakis, 2007; Arechavala-Lopez et al., 2013), this study will mainly focus on the rest of the Mediterranean farmed fish species.

Methods

Data and calculations

The somatic yields that were reviewed or calculated from the respective literature were the following:

$$\text{Filleting yield}\left(\text{FY}\right) = \left[100 \times \left(\text{fillet weight } / \text{ body weight}\right)\right],$$
$$\text{Viscerosomatic index}\left(\text{VSI}\right) = \left[100 \times \left(\text{total viscera weight } / \text{ body weight}\right)\right],$$
$$\text{Hepatosomatic index }\left(\text{HSI}\right) = \left[100 \times \left(\text{liver weight } / \text{ body weight}\right)\right] \text{ and}$$
$$\text{Condition index }\left(\text{CI}\right) = \left[100 \times \text{ body weight }\left(\text{g}\right) / \text{ body length}^3\left(\text{cm}^3\right)\right]$$

The fillet quality was assessed in terms of total composition (moisture, protein, ash and fat percentages) and in terms of fatty acid composition. For the latter, the percentages of the main fatty acid groups were calculated, i.e. saturates (SUFA), monounsaturates (MUFA), n-3 polyunsaturates (n-3 PUFA) and n-6 polyunsaturates (n-6 PUFA), as well as the two important n-3 fatty acids, the eicosapentaenoic (20:5n-3, EPA) and docohexaenoic (22:6n-3, DHA).

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Besides, for estimation of the actual nutritional value of n-3 PUFA their total contents and the contents of EPA and DHA in 100g fish fillet were calculated as:

(Fatty acid % × fillet fat %) / 100.

For all of the above factors, the weighed mean was calculated in the wild and farmed fish.

Study restrictions and limitations

It is important to notice that all data considered within this study refer to fish near or at commercial weights. Furthermore, for species with wider geographical distribution, the data for wild fish limits only in Mediterranean populations, since the environment has an important impact in all biological parameters and therefore in the end product quality (Love, 1992). Thus, taking into account fish of the same species but different origins (e.g. the Atlantic, the Black Sea or the Red Sea) was considered to be misleading.

Among the farmed species in the Mediterranean, the Atlantic bluefin tuna was not taken into account for this study since its aquaculture is far from achieving a complete cycle production, includes only fattening and is based on feeding with fresh fish instead of commercial diets (Grigorakis and Rigos, 2011; Hattour and Couchet, 2014).

The red drum (*Sciaenops ocellatus*) was not included in this study either. Although its farming has been established in Israel since the ‘90s (Diamant, 1998), this decision was due to the facts that this species does not naturally inhabit the Mediterranean (FishBase, 2011) and that all sources referring to its quality features refer to geographic origins other than the Mediterranean (Craig et al., 2000; Recks and Seaborn, 2008; Li et al., 2013).

A small part of the literature referring to the quality of the studied species was not taken into account for not providing information that allow calculations on whole wet fillet basis (Hernández et al., 2001; Hernández et al., 2003; Bonaldo et al., 2004; Rondán et al., 2004; Lloret et al., 2005; Testi et al., 2006; Álvarez et al., 2009; Álvarez et al., 2009b; Haouas et al., 2010; Nogales Merida et al., 2011; Valente et al., 2011), and for calculating fatty acid compositions of lipid fractions without providing the relative proportions of these lipid fractions (Regost et al., 2003; Varljen et al., 2003).

For all studied parameters weighed means were calculated, taking into account the literature average values and the number of individuals analyzed in each study. In cases that sample size was not evident (Rueda et al., 1997; Soriguer et al., 1997; El-Dakar et al., 2007; Koubaa et al., 2011), a n=3 was assumed on the basis that this is the minimum size for statistical analysis in the respective studies.

Metanalysis

For comparisons of average values $\bar{X}$ between farmed (F) and wild (W) individuals of the same species, effect size was evaluated by the use of Hedges *d* (Hedges and Olkin 1985):

$$d = \frac{\overline{X}_F - \overline{X}_W}{s_p} J \qquad (1)$$

where the correction for bias

$$J = 1 - \frac{3}{4(n_F + n_W) - 9} \qquad (2)$$

and

$$s_p = \sqrt{\frac{(n_F - 1)se_F^2 + (n_W - 1)se_W^2}{n_F + n_W - 2}} \qquad (3)$$

The asymptotic standard error (*se*) of the effect size was calculated as following:

$$s_e = \sqrt{\frac{n_F + n_W}{n_F n_W} + \frac{d^2}{2(n_F + n_W - 2)}} \qquad (4)$$

Precision of *d* with 95% confidence intervals was evaluated as *d*-1.96*se* to *d*+1.96*se*.

Biometric parameters and yields

The filleting yield is an important parameter, especially for species that filleting is among their custom processing, because it describes their actual edible gain. The respective data for the Mediterranean farmed fish is actually limited to some species, mainly meagre, dentex (*Dentex dentex*) and shi drum (Table 2). For the rest of the species, lack of data for some of them (like porgies *Pagellus* sp., annular seabream *Diplodus annularis* and mullets *Mugil* sp. and *Liza* sp.) may be due to the fact that they are not customly commercialized in filleted forms. However, for some other such as the flatfishes (*Solea* sp., *Psetta maxima*), red seabream (*Pagrus* sp.), dentex, greater amberjack and brown meagre, filleting is of interest and the collection of respective data should be within the aims of future research. Existing data show that the filleting yields for most species are around 40-45 % with few exceptions of extremely high and low yields reported for sharpsnout seabream (*Diplodus puntazzo*) and white seabream (*Diplodus sargus*), respectively (Table 2).

The viscerosomatic index (VSI) is a measure for the estimation of the visceral fat deposition and together with the hepatosomatic index (HSI) that represents the hepatic weight (Table 2), consist a way to evaluate the technical loss from fish gutting. The species with the lowest visceral losses are the flatfishes (*Solea senegalensis* and *Psetta maxima*), as becomes evident from the VSI values in Table 2. Also the Sciaenidae family species (*Argyrosomus regius*, *Sciaena umbra*, *Umbrina cirrosa*) appear to have low visceral losses (Table 2). The obvious reason for that is their low visceral fat deposition (Poli et al., 2003; García Mesa et al., 2014).

The condition index (CI) is indicative of the feeding condition of the fish and has been shown to increase in well-fed fish, like in the intensive farming-originated fish in comparison with extensively farmed and wild fish (Floss et al., 2002; Grigorakis, 2007; Piccolo et al., 2007; Martelli et al., 2013).

When concerning the CI, only intra-species comparisons are meaningful, since possible differences between species is most likely to be due to their different allometry. The latter for instance, becomes evident by the significantly lower condition indexes found for turbot and Senegalese sole than for the rest of the species (Table 2), obviously attributed to the different body geometry.

Metanalysis for the technical yields was possible only for VSI in the case of sharpsnout sea bream, where data are available in sufficient numbers for both wild and cultured counterparts (Table 2). A Hedges *d* index of 12.87 indicated statistically significant difference ($p<0.01$) with farmed fish exhibiting higher VSI. This can be explained as a higher visceral fat deposition for farmed fish, a fact that was also confirmed in one study that directly compared wild and farmed sharpsnout sea bream (Rueda et al., 2001).

Technical yields of Mediterranean species seem to be affected in various ways by environmental parameters, feeding and ploidy, and although the respective research is sporadic and sometimes contradictory, this is summarized in Table 3.

Technical yields, being of importance because they define the edible part of the products, show differentiations based on species, season and dietary history. Data on filleting yields are limited only to some of the species. For many species that filleting is expected to be of commercial interest, a monitoring of filleting yield is required in the future. Although sporadic data are available on the effects of dietary treatments and season in the fillet percentage, an important issue that needs to be addressed is the effect of fish size. This will be particularly useful in defining the best sizes for optimizing the filleting in each species. The herein results (Table 2) indicate that a technical loss of more than 50% during filleting, should be counterbalanced by the added value of the produced fillet. In regard with the filleting yield differentiation, none of the studied species seems to be more advantageous to others and therefore factors, other than technical ones, would determine economic efficiency.

The viscerosomatic index, defining the yield of eviscerated fish, seems to be lower for two fish categories, the flatfishes and the meagres. This can be advantageous for the commercialization of these fish in gutted forms. The condition index is meaningful for intra-species comparisons and can be potentially used as a tool for traceability issues between wild and farmed fish.

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Fillet composition and fatty acids

The fillet composition is an important quality aspect since it largely defines the fish nutritional value and is also closely associated with its sensory attributes in the way they are perceived by the consumer (Grigorakis, 2007; Grigorakis, 2010). In general, with few exceptions, there is sufficient data on the fillet composition of the Mediterranean farmed fish species and in particular with their fillet fat.

The only important exception is that of wild meagre, where data is limited to those deriving from Sinanoglou et al. (2014). However, there is a serious probability that these authors have mistaken their so-assumed wild specimens. This can be postulated by the fact that they mentioned a fatty acid profile with high n6 fatty acids and in specifically of the 18:2n6 (linoleic acid) which is scarce in marine food chain and characterizes farmed fish due to its dietary terrestrial plant oil origin (Tocher, 2003; Linder et al., 2010). A potential explanation is that the authors have been probably provided with farmed escapees.

In general, the fillet protein of all fish species is quite similar, nearing a 20% of total fillet constituents. Fillet protein is generally believed to be stable in fully grown fish and not to be influenced by external parameters (Love, 1992; Grigorakis, 2010). However, there have been some cases where seasonal changes have been reported for wild fish populations (Gökçe et al., 2004; Saoud et al., 2008). Reduction of muscle protein in adult fish has been mentioned in cases of mobilization under prolonged fasting (Love, 1992).

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The fillet fat ranges between the various fish species. Among them, there are two categories, the flatfishes (*Psetta maxima*, *Solea senegalensis*, *Solea Solea*) and the Sciaenidae family (*Argyrosomus regius*, *Sciaena umbra* and *Umbrina cirrosa*) that have low fillet fat when compared to the rest of the fish (Table 4).

The meta-analysis results for fillet fat content comparisons between wild and farmed counterparts include dentex, sharpsnout sea bream, red porgy (*Pagrus pagrus*), common sole and brown meagre (Table 5). In all cases, the farmed counterparts were found to have increased muscle fat comparing to the wild ones. The higher fat contents in farmed animals have been confirmed by direct comparisons in individual studies for dentex (Dincer et al., 2010), sharpsnout sea bream (Rueda et al., 2001; Dincer et al., 2010), white seabream (Cejas et al., 2004), blackspot seabream (Álvarez et al., 2009), red porgy (Rueda et al., 1997; Loukas et al., 2010), brown meagre (Cakli et al., 2006; Dincer et al., 2010) and greater amberjack (Haouas et al., 2010; Rodriguez-Barreto et al., 2012).

The fillet fat even within the same species is highly dependable to various internal and external parameters, and therefore effects of season, for both wild and farmed counterparts, and feeding characteristics and intensity for farmed fish have been demonstrated in Mediterranean species (Table 6)

The fatty acid profiles of all studied Mediterranean fish are rich in n-3 polyunsaturated fatty acids (Table 7). Results of metanalysis, available for dentex, sharpsnout sea bream, red porgy, brown meagre and common sole (Table 5) indicated differences in fatty acid profiles between farmed and wild counterparts. The general pattern observed is the higher n-6 content of the former ones, with the only exception of the red porgy where higher n-6 levels have been found in wild fish. The fact that the one out two studies contributed to the metanalysis, found almost double n-6 contents in wild fish (Rueda et al., 1997) is responsible for this. The former authors although found higher 18:2n6 contents in farmed fish, in agreement with the general rule, they mentioned 9 times higher 20:4n6 in wild individuals.

In studies directly comparing wild and farmed individuals, significantly higher DHA contents have been observed in farmed counterparts for brown meagre and dentex (Dincer et al., 2010) and for sharpsnout sea bream in one case (Piccolo et al., 2007), while the opposite trend has been mentioned for sharpsnout sea bream in a second case (Dincer et al., 2010), for red porgy (Loukas et al., 2010) and greater amberjack (Haouas et al., 2010). EPA has been found to be higher in farmed fish for red porgy (Loukas et al., 2010), dentex, brown meagre (Dincer et al., 2010) and greater amberjack (Haouas et al., 2010) but similar (Piccolo et al., 2007) or higher (Dincer et al., 2010) in wild fish for sharpsnout sea bream.

When fatty acids are expressed as contents per 100g fish fillet, it becomes evident that Mediterranean fish species are highly nutritious and that their consumption can easily fulfill the n-3 PUFA daily needs (Table 8). It is worth mentioning that even species with low fat contents (flatfish and meagres) can cover a significant part of these needs. A comparison in total n-3, EPA and DHA contents between farmed and wild counterparts is always in favor of the former ones, obviously due to their higher fillet fat. This contradicts the general consumer impressions who perceive the farmed fish as of inferior nutritional quality (Claret et al., 2014).

The general rule of muscle fatty acids reflecting the dietary ones, applies for all Mediterranean farmed fish. Within these frames, inclusion of plant oils such as safflower oil (Altundag et al., 2014), soybean oil (Regost et al., 2003; Piedecausa et al., 2007), linseed oil (Regost et al., 2003; Piedecausa et al., 2007) or mixtures of vegetable oils (Valente et al., 2011) have shown to increase the n6 contents. Inclusion of animal fat (such as lard) to replace fish oil, leads into increase of muscle SFA and reduction of n3 PUFA and n3/n6 ratio (Nogales Merida et al., 2011b). For the herein studied species, fasting has been evaluated in common sole; muscle saturated fatty acids increased during starvation while PUFAs decreased, opposing the general rule that implies preservation of PUFAs and consumption of SFA with fasting (Fonseca et al., 2013).

Although, it is very difficult to make direct correlations of flesh fatty acids in wild fish with feeding habits, a very interesting recent observation indicated the depletion of PUFAs, EPA, DHA and ARA in particular, in wild white seabream due to consumption of the invasive algae *Caulerpa racemosa* (Felline et al., 2014)

Rearing system is, in some cases, influential to the muscle fatty acids, like one study that showed fatty acid differentiation between cage-reared and tank-reared meagre receiving the same diet (Martelli et al., 2013). It is not exactly clear what the causes of these differences. Perhaps the stocking density is one of the regulating factors in these cases (Piccolo et al., 2008), although this has not been always confirmed (Roncarati et al., 2006). Usually, the stocking density seems to have a more profound effect in the liver fatty acids, as a result to respective metabolic adaptations (Montero et al., 1999; Karakatsouli et al., 2007). The stocking density-derived

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differences, however, can be potentially attributed to feed intake differences (Lund et al., 2013). The other potential regulating factor in different rearing systems is the water temperature, or the general seasonal differences, which is discussed in the following.

Season may have an impact on the muscle fatty acids of temperate water fish. An increase of the unsaturation level, primarily in the polar lipid fraction, has been associated to the water temperature drop, in order to maintain the membrane fluidity (Hazel and Prosser, 1974; Love, 1992; Delgado et al., 1994). Furthermore, a seasonal depletion in MUFA, and in particular in oleic acid (18:1n9) is correlated with mobilization during gonadal development and this is of importance in species that maturation occurs at commercial size (Sargent, 1995; Özyurt and Polat, 2006). In wild fish, seasonality in fatty acids, has been noticed for several Mediterranean populations (Gökçe et al., 2004; Cakli et al., 2006; Özyurt et al., 2005; Özoğul et al., 2011b).

Studies referring to farmed Mediterranean populations, in specific gilthead sea bream, common sea bass and meagre (Senso et al., 2007; Yildiz et al., 2006; Yildiz et al., 2008; García Mesa et al., 2014), indicated minor or absolute absence of season-related fatty acid changes. García Mesa et al. (2014) justified this lack of markedly seasonal effects, to the high winter temperatures occurring in the Mediterranean. Nevertheless, a common weakness of the majority of the existing studies, is that seasonal effect is not individually studied and that other parameters, such as growth (Hernández et al., 2003; Poli et al., 2003; García Mesa et al., 2014), fish size (Martelli et al., 2013b) or variable genetic origin (Cardinal et al., 2011) interfere. Therefore, the examination of seasonal impact would require a comparison in fish of similar weights, dietary history and genetic uniformity, at different year intervals. Chatzifotis et al. (2004) having studied the fatty acid changes of dentex from the age of 8 to 36 months, i.e. for a period longer than two years, provided some data that allow conclusions in regard with the seasonal effect. Thus, irrespective to the fish weight (unfortunately not provided in the respective reference), a similar annual pattern can be observed with the fish always exhibiting a minimum of DHA and n3 fatty acids in Ferbruary and a maximum in October, while the exactly opposite pattern applied for total MUFA (Fig. 1). On the other side, no specific pattern was observed for the rather stable levels of SFA, total n6 and EPA. These findings contradict the absence of season-related changes mentioned by the aforementioned studies. These also imply that EPA which is conserved, unlike DHA that fluctuates, plays an important biological role.

Based on the fillet composition, it becomes evident that species can be distinguished in low fat species and fat accumulating ones, with the former ones including the meagres and the flatfishes. In all species, the general rule of higher fillet fat contents in farmed specimens has been confirmed for all species (Table 4).

The fatty acid profiles showed differentiation between wild and farmed specimens for all species (where data are sufficient). These fatty acid differences can be justified based, firstly on the general rule of dietary fatty acids reflection in fish flesh, and secondly on the seasonal changes related to temperature adaptations and gonadal maturation. The daily needs of an adult in n-3 PUFA are covered in most cases even by the consumption of 100g fish, due to the high unsaturation level of the fatty acids in all studied species. Farmed fish retain a nutritional advantage over wild ones due to their higher n-3 contents.

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Organoleptic quality of Mediterranean farmed fish

Sporadic data occur in aspects of the organoleptic quality of the Mediterranean farmed species. Acceptability comparisons have been made between two different farmed sparidae species, the sharpsnout sea bream and gilthead sea bream (Hernández et al., 2001b), which were always in favour of the gilthead sea bream probably due to its familiarity for the consumers. However, the hedonic test participants were well disposed towards both species.

Difference tests and blind acceptability studies have been also conducted between meagre of different sizes (Gonçalves et al., 2011; Giogios et al., 2013; Ribeiro et al., 2013; Saavedra et al., 2015) mainly to resolve the market rumor of quality inferiority in fish weighing less than 1 Kg (Monfort, 2010; FAO, 2013; Ribeiro et al., 2013). All respective studies showed similarities in their findings, i.e. significant sensory difference between smaller (<1Kg) and larger fish (>1Kg), high acceptability for fish with weights ranging between 500g and 1Kg although preference remained higher for larger fish. The assumption that the major quality feature responsible for better acceptability of large fish is the size-dependent texture differentiation, was supported in some cases (Gonçalves et al., 2011; Ribeiro et al., 2013) but not in other (Giogios et al., 2013; Saavedra et al., 2015).

Organoleptic comparisons between wild and cultured fish have been taken place for gilthead sea bream and sea bass in some cases and these have been reviewed in the past (Grigorakis, 2007; Arechavala-Lopez et al., 2013), while sporadic data occur for other species, for the brown meagre in specifically (Cakli et al., 2006). In all cases wild fish are characterized by reduced fatiness of their fillet, perceived flavour differences, and a darker appearance of the muscle

(Cakli et al., 2006; Grigorakis, 2007; Arechavala-Lopez et al., 2013). Besides wild and farmed fish sensory differences, the rearing environment can also have an impact on fish sensory properties. In particular freshwater and seawater-reared red drum was found different in aspects of colour and texture; seawater-rearing resulted into lower hardness and color intensity (Klanian and Alonso, 2013).

A number of studies attempt to evaluate the impact of the diet on the sensory properties of produced fish. Fish oil and fishmeal substitution by plant raw materials (Izquierdo et al., 2005; Izquierdo et al., 2005; Cabral et al., 2013; Matos et al., 2012; Moreira et al., 2014) and the differentiation of dietary fat levels (Lopparelli et al., 2004) mostly resulted in minor or no sensory changes, mainly limiting in fillet color alterations (Izquierdo et al., 2005; Segato et al., 2005b; Matos et al., 2012). Otherwise, no other impact was observed in aspects of aroma or mouth sensation (texture or flavor of the fish). In some studies, however, dietary interventions have been found to affect sensory-perceived texture in case of fishmeal subtitution (Hernández et al., 2007) or odour intensity in cases of dietary fat elevation (Segato et al., 2008). What can be assumed is that the species-characteristic fat accumulation and muscle microstructure, as well as the differential dietary requirements may differentiate the way that each species' sensory quality responds to the dietary treatments.

The existing data, so far provide evidence that sensory quality of fish can be altered subject to fish feeding history, somatic size and rearing environment. However, the sporadic results and the absence of analytic tools, i.e. descriptive analysis methods for describing Mediterranean fish species, do not allow safe conclusions on the degree and direction of these organoleptic changes.

Overall critical conclusion-recommendations

The Mediterranean farmed fish species offer a perspective upon which aquaculture diversification can be based. Their somatic yields and their fillet composition are important determinants of their overall quality and of the alternative ways of their commercialization.

The filleting yield for most of the farmed species is within a range of 40-45%. Herein data indicated that the viscerosomatic index differs among species, with flatfishes and Sciaenidae species exhibiting low visceral losses when compared to the rest of the Mediterranean farmed species. It is therefore suggested that the representatives of these two families have an advantage when commercialized in gutted forms, due to the low technical loss.

The condition index is related to the body geometry of each species, can be indicative of the feeding condition of the fish, and can be also a useful tool to discriminate wild from farmed counterparts of the same species.

In aspects of fillet composition, present review indicated that some flatfishes and meagres have very low muscle fat contents. This feature differentiates them from the rest of the farmed species. All farmed fish that were herein reviewed, have been found to contain high n-3 PUFA. Farmed fish differ in their fatty acid composition from their wild counterparts. The most characteristic differences are the significantly higher muscle fat contents and the higher n-6 (mainly 18:2n-6) contents in farmed fish. The aquaculture management, dietary treatment and season can impact on farmed fish fillet composition and fatty acid quality, while season largely affects lipid quality in wild fish through food availability and maturation process.

We herein indicated that for some species that their aquaculture is long established such as the meagres, there is lack of comparisons with the respective wild individuals. Their farming and commercialization is largely based on the well established knowledge for gilthead sea bream and sea bass. This results into defective perception or speculations on their actual dietary needs and their produced quality capacities. The establishment of future comparisons with wild fish would elucidate answers in respect to quality individualities (e.g. due to different fatty acid metabolism in meagres (Monroig et al., 2013)) and the "ideal" in their quality.

Contrary to the fillet proximate composition and the fat qualities that received lerge attention by scientists, the sensory characteristics of the vast majority of the Mediterranean farmed species have not been described systematically. Most of the existing literature focuses on examining whether specific management or dietary treatments differentiate the sensory quality of the fish when compared to control groups. The development of sensory description tools for the herein studied species, such as descriptive analysis, should be within future research priorities in order to gain knowledge of their sensory characteristics and factors affecting them.

Based on the herein observations of the quality features in the farmed Mediterranean fish, it becomes evident that species diversification can also provide products diversification. First of all, different species can be commercialized in various forms. The fish with larger commercial weights, such as the meagres or the greater amberjack can provide a wider variety of products, based on fillets or cuts.

The Mediterranean farmed fish can also provide flesh with different nutritional specifications. Within these frames, the muscle fat is a determinant of the commercialization potential of each species. Fish of low fillet fat, such as flatfish and meagres, independently of their commercial sizes, can be recommended in low fat diets. Those species that accumulate muscular fat, like the medium-fat species that include all the sparids and the common sea bass, can be proposed as good candidate foods for n-3 rich diets since their EPA and DHA contents largely exceed the minimum daily recommended intake. The confirmed difference in the fillet fat of wild and cultured specimens, for all species, can be used in advantage of the fattier farmed fish, considering the high unsaturation level in the fatty acids of all species.

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Table 1: Mediterranean marine finfish aquaculture production in tonnes. The groupers, *Epinephelus spp.* and wreckfish *Polyprion americanus* are not included since no commercial production has been recorded in the Mediterranean. Data refer to 2009 official production numbers (except † that refer to 2003 and ‡ to 2008 last maximum recorded quantities). Source: FAO, 2010.

Common name	**Scientific name**	**Main producers in the Mediterranean**	**Total Medit. production**	**Total world production**
Grey mullet, striped mullet	*Mugil cephalus*	Egypt	213,194	221,978
Other mullets	Mugilidae	Italy, Spain	390	9,078
Sea bass	*Dicentrarchus labrax*	Turkey, Greece, Spain	111,764	112,183
Gilthead sea bream	*Sparus aurata*	Greece, Turkey, Spain	133,124	136,070
Common sole	*Solea solea*	Italy, Spain	16	30
Senegalese sole	*Solea senegalensis*	Spain	63	63
Turbot	*Psetta maxima*	Spain	7,188	69,.006
Brown meagre	*Sciaena umbra*	Spain	30†	30†
Shi drum	*Umbrina cirrosa*	Italy	45‡	45‡

Meagre	*Argyrosomus regius*	Egypt, Spain, France	4,068	4,112
Red drum	*Sciaenops ocellatus*	Israel	459	51,476
Blackspot seabream	*Pagellus bogaraveo*	Spain	183	183
Common pandora	*Pagellus erythrinus*	Greece	42	42
White sea bream	*Diplodus sargus*	Greece, Italy	104	105
Two-banded sea bream	*Diplodus vulgaris*	Italy	18‡	18‡
Sharpsnout seabream	*Diplodus puntazzo*	Italy	51	51
Common dentex	*Dentex dentex*	Boznia, Spain	10	10
Red Porgy	*Pagrus pagrus*	Cyprus, Greece	23†	23†
Other porgies	*Pagrus* spp.	Cyprus	10	10
Other sparids	Sparidae	Italy	65	42,827
Marbled spinefoot (or rabbitfish)	*Siganus rivulatus*	Cyprus	2	2
Atlantic bluefin tuna	*Thunnus, thynnus*	Croatia, Malta	1,994	1,999
Greater amberjack	*Seriola dumerili*	Spain	1	4

Table 2: Technological and somatometric characteristics of farmed Mediterranean fish species. Values are weighed means. In parenthesis the total number of studies taken into account and the total number of fish that contributed to the weighed mean.

species		**FY**	**VSI**	**HSI**	**CI**	**References**
Argyrosomus regius	Farmed	43.3 (6/266)	4.96 (4/204)	1.50 (3/194)	1.05 (2/154)	Poli et al., 2003; Grigorakis et al., 2011; Giogios et al., 2013; Martelli et al., 2013; Nathanailides et al., 2013; Sinanoglou et al, 2013
Dentex dentex	Farmed	44.7 (2/306)	5.16 (2/306)	1.85 (3/342)	1.51 (3/342)	Pérez-Jimenez et al., 2009; Suárez et al., 2009; Suárez et al., 2010
Diplodus annularis	wild	-	7.32 (1/16)	1.28 (1/16)	-	Ketata Khituni et al., 2010
Diplodus puntazzo	Farmed	51.3 (1/54)	3.93 (6/215)	1.45 (6/232)	2.03 (6/237)	Hernández et al., 2001; Nogales-Merida et al., 2001b; Rueda et al., 2001; Hernández et al., 2003; Piccolo et al., 2007; Piedecausa et al., 2007; Piccolo et al., 2013
	wild	-	3.15 (2/65)	1.95 (1/60)	1.93 (1/60)	Rueda et al., 2001; Piccolo et al., 2007
Diplodus	wild	29.3	-	-	-	Saoud et al., 2008

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sargus		(1/120)				
Liza aurata	wild	-	9.19 (1/13)	2.26 (1/13)	-	Ketata Khituni et al., 2010
Pagellus bogaraveo	farmed	-	8.41 (3/108)	1.24 (4/136)	2.70 (3/132)	Palmegiano et al., 2007; de Almeida Ozório et al., 2009; Figueiredo Silva et al., 2010; Valente et al., 2010.
Pagrus pagrus	farmed	-	6.81 (3/95)	1.64 (3/95)	3.13 (1/45)	Rueda et al., 1998; García et al., 2010; Kalinowski et al., 2015
Psetta maxima	farmed	-	3.66 (2/105)	1.57 (2/105)	1.42 (2/81)	Regost et al., 2003; Altundag et al., 2014; Sevgili et al., 2014
Siganus rivulatus	farmed	-	14 (1/25)	3.46 (1/25)	2.46 (1/25)	El-Dakar et al., 2007
	wild	36.7 (1/120)	-	-	-	Saoud et al., 2008
Solea senegalensis	farmed	-	1.49 (2/228)	1.17 (2/228)	1.51 (1/180)	Valente et al., 2011 ; Cabral et al., 2013
Umbrina cirrosa	farmed	40.5 (2/132)	4.19 (3/156)	2.45 (2/48)	2.12 (3/156)	Segato et al., 2005; Segato et al., 2005b; Segato et al., 2007

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Table 3: Effects of influencing parameters in the technical yields and condition index of Mediterranean farmed species, or wild counterparts.

Species	**Influencing Parameter**	**Effect**	**References**
Filleting yield			
Diplodus puntazzo	inclusion of vegetable oil in diet	increase	Piedecausa et al., 2007
Dentex dentex	various dietary protein and fat levels	none	Suárez et al., 2009
	5 weeks starvation	increase	Suárez et al., 2010
Siganus rivulatus (wild)	Season	lowest yields in March & October	
A. regius	Fish growth / season	none	Saoud et al., 2008
VSI			
Sciaena umbra	dietary fat increase	increase	Segato et al., 2005
	inclusion of vegetable oil in diet	increase	Segato et al., 2005b
Solea senegalensis	Fish meal substitution by plant meals	increase	Valente et al., 2011; Cabral et al., 2013
Dentex dentex, *Diplodus puntazzo*, *Pagellus*	Fish meal and fish oil substitution by plant raw materials	none	Palmegiano et al., 2007; Suárez et al., 2009; Nogales-Merida et al.,

bogaraveo			2011, Piccolo et al., 2013
Sciaena umbra	triploidy	increase	Segato et al., 2007
A. regius	season	variable seasonality	Poli et al., 2003; Martelli et al., 2013
CI			
Pagellus bogaraveo	feeding intensity increase	increase	deAlmeida Ozório *et al.*, 2009
Dentex dentex	5 weeks starvation	decrease	Suárez et al., 2010
Argyrosomus regius	Fish growth / season	none	Poli *et al.*, 2003; Martelli *et al.*, 2013
Dentex dentex, Diplodus puntazzo, Pagrus pagrus, Solea senegalensis, Umbrina cirrosa,	diet composition	none	Hernández et al., 2001; Segato et al., 2005; Palmegiano et al., 2007; Piedecausa et al., 2007; Pérez-Jimenez et al., 2009; Suárez et al., 2009; García et al., 2010; Valente et al., 2011; Nogales-Merida et al., 2013; Piccolo et al., 2013

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Sciaena umbra	triploidy	decrease	Segato et al., 2007
Diplodus puntazzo	season	Increase when closing reproductive season (September)	Hernández et al., 2003

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Table 4: Fillet proximate composition of farmed Mediterranean fish species. Values are weighed means. In parenthesis the total number of studies taken into account and the total number of fish that contributed to the weighed mean.

species		**Moisture %**	**Protein %**	**Ash %**	**Fat %**	**References**
Argyrosomus regius	Farmed	72.8 (6/212)	20.5 (3/120)	1.34 (4/150)	2.12 (7/218)	Poli et al., 2003; Hernández et al., 2009; Grigorakis et al., 2011; Nevigado et al., 2012; Giogios et al., 2013; Martelli et al., 2013; Sinanoglou et al., 2013
Dentex dentex	Farmed	73.1 (4/329)	20.2 (4/329)	2.94 (2/36)	3.78 (4/329)	Ozden and Erkan, 2008; Suárez et al., 2009; Suárez et al., 2010; Dincer et al., 2010
	wild	75.2 (1/5)	22.1 (2/8)	-	1.91 (2/8)	Soriguer et al., 1997; Dincer et al., 2010
Diplodus annularis	wild	-	-	-	0.92 (1/3)	Özoğul et al., 2008
Diplodus puntazzo	Farmed	70.5 (3/16)	19.2 (3/16)	1.23 (2/11)	8.39 (4/20)	Orban et al., 2000; Rueda et al., 2001; Cakli et al., 2008; Dincer et al., 2010

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	wild	76.7 (1/5)	19.2 (1/5)	-	2.80 (3/13)	Rueda et al., 2001; Özoğul et al., 2008; Dincer et al., 2010
Diplodus sargus	farmed	76.4 (1/9)	-	-	5.82 (1/9)	Cejas et al., 2004
	wild	77.4 (2/129)	19.3 (2/129)	1.76 (2/129)	1.51 (5/141)	Hornung et al., 1994; Soriguer et al., 1997; Özyurt et al., 2005; Saoud et al., 2008
Diplodus vulgaris	wild	76.7 (1/10)	-	-	2.27 (3/23)	Varljen et al., 2003; Özoğul et al., 2008; Prato and Biandolino 2012
Epinephelus auneus	wild	77.6 (1/18)	19.7 (1/18)	1.57 (1/18)	0.77 (1/18)	Özoğul et al., 2011b
Liza aurata	wild	74.5 (1/9)	20.1 (1/9)	1.42 (1/9)	4.51 (3/22)	Kamden et al., 2008; Özoğul et al., 2008; Prato and Biandolino 2012
Liza ramada	wild	74.4 (1/9)	19.8 (1/9)	1.58 (1/9)	3.25 (3/15)	Kamden et al., 2008; Özoğul et al., 2008 ; Nevigado et al., 2012
Liza saliens	wild	76.0 (1/9)	18.5 (1/9)	1.28 (1/9)	2.87 (2/12)	Kamden et al., 2008; Özoğul et al., 2008

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Mugil cephalus	farmed	76 (1/6)	-	-	10.0 (1/6)	El-Sebaiy et al., 1987
	wild	-	-	-	2.10 (2/7)	Özoğul and Özoğul 2007; Özoğul et al., 2008
Pagellus bogaraveo	farmed	72.2 (1/36)	19.8 (1/36)	1.66 (1/36)	7.26 (4/120)	Palmegiano et al., 2007; de Almeida Ozório et al., 2009; Figueiredo Silva et al., 2010; Valente et al., 2010.
	wild	-	21.1 (1/3)	-	4.32 (1/3)	Soriguer et al., 1997
Pagellus erythrinus	wild	75.9 (2/36)	18.1 (2/36)	1.54 (2/36)	3.86 (3/40)	Özoğul and Özoğul 2007; Koubaa et al., 2011; Koubaa et al., 2014
Pagrus pagrus	farmed	74.7 (1/24)	21.6 (1/24)	1.70 (1/24)	4.19 (3/47)	Rueda et al., 1997; Loukas et al., 2010; Kalinowski et al., 2015
	wild	-	-	-	0.85 (2/24)	Rueda et al., 1997; Loukas et al., 2010
Psetta maxima	farmed	77.4 (2/24)	20.1 (2/24)	-	1.57 (3/27)	Regost et al., 2003; Nevigado et al., 2012; Altundag et al., 2013

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	wild	-	20.4 (1/3)	-	0.97 (1/3)	Soriguer et al., 1997
Sciaena umbra	farmed	74.1 (2/45)	20.2 (2/45)	-	3.18	Cakli et al., 2006; Dincer et al., 2010
	wild	74.7 (1/40)		-	1.40 (1/40)	Cakli et al., 2006
Seriola dumerili	farmed	71.7 (2/39)	23.2 (1/30)	-	6.65 (2/39)	Thakur et al., 2009; Rodriguez-Bareto et al., 2012
	wild	76.7 (1/9)	-	-	3.64 (1/9)	Rodriguez-Bareto et al., 2012
Siganus rivulatus	wild	76.7 (1/120)	19.7 (1/120)	1.39 (1/120)	1.95 (1/120)	Saoud et al., 2008
Solea senegalensis	farmed	-	19.5 (1/36)	-	1.47 (2/84)	Valente et al., 2011; Cabral et al., 2013
	wild	76.5 (1/5)	20.6 (1/5)	1.24 (1/5)	1.43(1/5)	Tejada et al., 2007
Solea Solea	farmed	76.9 (1/48)	19.6 (1/48)	1.15 (1/48)	2.65 (2/51)	Piccolo et al., 2008; Nevigado et al., 2012;
	wild	78.5 (4/70)	19.2 (4/70)	1.27 (4/70)	0.54 (5/74)	Gökçe et al., 2004; Özoğul and Özoğul, 2007; Ersoy et

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						al., 2008; Özoğul et al., 2011; Özoğul et al., 2011b
Umbrina cirrosa	farmed	75.9 (4/136)	20.8 (4/136)	1.26 (3/84)	1.65 (4/136)	Segato et al., 2005; Segato et al., 2005b; Segato et al., 2007; Segato et al., 2008
	wild	-	-	-	0.92 (1/3)	Özoğul et al., 2008

Table 5: Metanalysis results: Hedges *d* index for detection of differences between wild and farmed counterparts. The * and ** denote statistically significant differences ($p<0.05$ and $p<0.01$, respectively).

Species	**Muscle Fat**	**SFA**	**MUFA**	**n-3 PUFA**	**n-6 PUFA**	**EPA**	**DHA**
Dentex dentex	17.8**	2.90**	5.15**	7.15**	10.5**	1.59*	7.40**
Diplodus puntazzo	5.77**	18.7**	0.27	7.49**	7.55**	2.90**	3.05**
Pagrus pagrus	26.4**	9.79	8.88**	4.00**	4.28**	2.42**	10.2**
Sciaena umbra	12.1**	26.6**	8.81**	13.3**	111.1**	-	-
Solea Solea	17.4**	8.31**	21.8**	0.89**	7.55**	6.26**	5.11**

Table 6: Factors influencing the fillet fat of Mediterranean farmed species, or wild counterparts.

Species	**Influencing Parameter**	**Effect**	**References**
Mugilidae, Sparidae	Fish size	Increase with size	Grigorakis, 2007; Ketata Kitouni et al., 2010
Wild populations of: *Dicentrarchus labrax*, *Diplodus sargus*, *Sciaena umbra*, *Siganus rivulatus*, *Sparus aurata*, *Solea solea*	Season	Increasing in the summer months, due to intensive feeding and elevated food availability. Maximum at the end of the warm period (late summer to mid autumn). Depletion in cold months.	Gökçe et al., 2004; Özyurt et al., 2005; Cakli et al., 2006; Özyurt and Polat, 2006; Senso et al., 2007; Ersoy et al., 2008; Saoud et al., 2008; Özoğul et al., 2011b
Farmed *Argyrosomus regius*, *Scieana umbra*, *Seriola dumerili*	Season	Depletion in cold months.	Poli et al., 2003; Cakli et al., 2006; Thakur et al., 2009
Solea senegalensis,	Dietary fat	none	Segato et al., 2005;

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Solea solea, *Umbrina cirrosa*			Piccolo et al., 2008; Valente et al., 2011
Hippoglossus hippoglossus	Dietary fat	Increase with fat level	Nortvendt and Tuene, 1998
Pagellus bogaraveo, *Psetta maxima*, *Solea senegalensis*, *Umbrina cirrosa*	fish meal and fish oil substitution by plant materials	none	Regost et al., 2003; Segato et al., 2005b; Palmegiano et al., 2007; Figueiredo-Silva et al., 2010; Cabral et al., 2013
Psetta maxima, *Solea senegalensis*	fish meal and fish oil substitution by plant materials	Increase in plant diets	Valente et al., 2010; Altundag et al., 2014
Pagellus bogaraveo, *Sparus aurata*	Feeding intensity	Increaseor increase tendency in highly-fed fish	Flos et al., 2002; deAlmeida Ozorio et al., 2009
Dentex dentex, *Sparus aurata*	fasting	Decrease in prolonged fasting	Grigorakis & Alexis, 2005; Suárez et al., 2010.

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Table 7: Fillet fatty acid composition (as % of total fatty acids) of farmed Mediterranean fish species. Values are weighed means. In parenthesis the total number of studies taken into account and the total number of fish that contributed to the weighed mean.

species		SFA	MUFA	n-3 PUFA	n-6 PUFA	EPA	DHA	References
Argyrosomus regius	Farmed	31.2 (7/192)	29.8 (7/192)	26.3 (6/174)	11.4 (6/174)	7.36 (6/174)	14.1 (6/174)	Hernández et al., 2009; Grigorakis et al., 2011; Nevigado et al., 2012; Giogios et al., 2013; Martelli et al., 2013; Sinanoglou et al., 2013
Dentex dentex	Farmed	31.3 (4/83)	27.4 (4/83)	25.9 (3/65)	8.02 (3/65)	4.76 (4/83)	16.5 (4/83)	Chatzifotis et al., 2004; Ozden and Erkan, 2008; Dincer et al.,

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								2010; Suárez et al., 2010
	wild	37.1 (2/8)	34.8 (2/8)	14.1 (2/8)	2.98 (2/8)	4.38 (2/8)	11.7 (2/8)	Sorigueret al., 1997; Dincer et al., 2010
Diplodus annularis	wild	38.4 (1/3)	31.0 (1/3)	12.7 (1/3)	3.9 (1/3)	3.44 (1/3)	8.79 (1/3)	Özoğul et al., 2008
Diplodus puntazzo	Farmed	27.0 (7/123)	35.6 (7/123)	25.0 (7/123)	12.4 (7/123)	5.81 (7/123)	9.65 (7/123)	Orban et al., 2000; Rueda et al., 2001; Rondán et al., 2004b; Piccolo et al., 2007; Piedecausa et al., 2007; Dincer et al., 2010; Piccolo et al., 2013
	wild	34.0 (4/73)	35.0 (4/73)	20.8 (4/73)	6.5 (4/73)	5.39 (4/73)	7.70 (4/73)	Rueda et al., 2001; Piccolo et al., 2007;

								Özoğul et al., 2008; Dincer et al., 2010
Diplodus sargus	farmed	31.8 (1/9)	23.1 (1/9)	36.3 (1/9)	5.99 (1/9)	6.04 (1/9)	25.1 (1/9)	Cejas et al., 2004
	wild	37.7 (3/129)	25.4 (3/129)	16.4 (3/129)	7.59 (3/129)	5.45 (3/129)	9.91 (3/129)	Hornung et al., 1994; Özyurt et al., 2005; Özyurt et al., 2006; Özoğul et al., 2008;
Diplodus vulgaris	wild	37.2 (2/13)	25.2 (2/13)	27.1 (2/13)	7.06 (2/13)	6.95 (2/13)	18.3 (2/13)	Özoğul et al., 2008; Prato and Biandolino 2012
Epinephelus auneus	wild	30.9 (1/18)	15.1 (1/18)	34.2 (1/18)	7.08 (1/18)	4.60 (1/18)	29.3 (1/18)	Özoğul et al., 2011b
Liza aurata	wild	33.8 (3/22)	42.4 (3/22)	13.1 (3/22)	6.98 (3/22)	5.16 (3/22)	6.04 (3/22)	Kamden et al., 2008; Özoğul et al.,

								2008; Prato and Biandolino, 2012
Liza ramada	wild	27.8 (3/15)	40.4 (3/15)	19.7 (3/15)	6.15 (3/15)	10.5 (3/15)	5.21 (3/15)	Kamden et al., 2008; Özoğul et al., 2008; Nevigado et al., 2012
Liza saliens	wild	27.3 (2/12)	40.8 (2/12)	18.3 (2/12)	7.81 (2/12)	13.2 (2/12)	2.60 (2/12)	Kamden et al., 2008; Özoğul et al., 2008
Mugil cephalus	wild	36.6 (2/7)	23.0 (2/7)	18.4 (2/7)	6.98 (2/7)	9.98 (2/7)	6.40 (2/7)	Özoğul and Özoğul 2007; Özoğul et al., 2008
Pagellus bogaraveo	farmed	30.3 (2/48)	34.2 (2/48)	18.5 (2/48)	9.40 (2/48)	4.82 (2/48)	9.71 (2/48)	Palmegiano et al., 2007; Figueiredo Silva et al.,

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								2010
	wild	30.6 (1/3)	30.6 (1/3)	26.3 (1/3)	3.17 (1/3)	8.6 (1/3)	13.5 (1/3)	Soriguer et al., 1997
Pagellus erythrinus	wild	52.7 (2/37)	38.8 (2/37)	5.48 (2/37)	1.57 (2/37)	1.18 (2/37)	2.95 (2/37)	Özoğul and Özoğul., 2007; Koubaa et al., 2014
Pagrus pagrus	farmed	31.2 (3/47)	42.1 (3/47)	20.7 (3/47)	5.84 (3/47)	5.58 (3/47)	12.8 (3/47)	Rueda et al., 1997; Loukas et al., 2010; Kalinowski et al., 2015
	wild	36.9 (2/24)	29.7 (2/24)	25.6 (2/24)	7.01 (2/24)	4.12 (2/24)	20.5 (2/24)	Rueda et al., 1997; Loukas et al., 2010
Psetta maxima	farmed	22.1 (2/9)	21.9 (2/9)	26.2 (2/9)	16.9 (2/9)	6.02 (2/9)	16.8 (2/9)	Nevigado et al., 2012; Altundag et al., 2013
	wild	28.8 (1/3)	23.6 (1/3)	37.2 (1/3)	4.15 (1/3)	8.00 (1/3)	24.5 (1/3)	Soriguer et al., 1997
Sciaena	farmed	41.5	37.8	12.3	8.14	-	-	Cakli et al.,

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umbra		(2/45)	(2/45)	(2/45)	(2/45)			2006; Dincer et al., 2010
	wild	52.1 (2/45)	33.3 (2/45)	8.99 (2/45)	2.85 (2/45)	3.21 (1/5)	6.45 (1/5)	Cakli et al., 2006; Dincer et al., 2010
Seriola dumerili	farmed	31. 6 (2/19)	27.4 (2/19)	25.5 (2/19)	14.0 (2/19)	7.57 (2/19)	12.8 (2/19)	Haouas et al., 2010; Rodriguez-Bareto et al., 2012
	wild	36.0 (1/9)	34.0 (1/9)	24.4 (1/9)	4.80 (1/9)	2.66 (1/9)	18.8 (1/9)	Rodriguez-Bareto et al., 2012
Solea senegalensis	farmed	28.1 (2/84)	24.5 (2/84)	32.1 (2/84)	10.2 (2/84)	3.65 (2/84)	20.8 (2/84)	Valente et al., 2011; Cabral et al., 2013
Solea Solea	farmed	25.5 (2/51)	34.4 (2/51)	20.5 (2/51)	9.37 (2/51)	4.70 (2/51)	13.1 (2/51)	Piccolo et al., 2008; Nevigado et al., 2012
	wild	29.2 (4/74)	16.9 (4/74)	24.0 (4/74)	7.32 (4/74)	3.90 (4/74)	19.5 (4/74)	Gökçe et al., 2004; Özoğul

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								and Özoğul, 2007; Ersoy et al., 2008; Özoğul et al., 2011b
Umbrina cirrosa	wild	40.9 (1/3)	23.0 (1/3)	24.0 (1/3)	1.69 (1/3)	6.52 (1/3)	17.0 (1/3)	Özoğul etal., 2008

Table 8: n-3 PUFA nutritional value of farmed Mediterranean fish species. Values are expressed as g/ 100g fish fillet. In the third column appears what % of daily recommended intake they represent, based on EFSA recommendation for healthy adults*.

Species		**n-3 PUFA**	**EPA+DHA**	**EPA+DHA (% Daily recommended intake)**
Argyrosomus regius	Farmed	0.56	0.45	181.9
Dentex dentex	Farmed	0.98	0.80	320.8
	wild	0.27	0.31	122.7
Diplodus puntazzo	Farmed	2.10	1.30	518.8
	wild	0.58	0.37	147.0
Diplodus sargus	farmed	2.11	1.82	726.8
	wild	0.25	0.23	92.6
Diplodus vulgaris	wild	0.62	0.57	229.1
Epinephelus auneus	wild	0.26	0.26	104.4
Liza aurata	wild	0.59	0.50	201.9
Liza ramada	wild	0.64	0.51	203.9
Liza saliens	wild	0.53	0.45	181.6
Mugil cephalus	wild	0.39	0.35	138.0
Pagellus bogaraveo	farmed	1.35	1.06	422.0
	wild	1.14	0.95	381.9

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Pagellus erythrinus	wild	0.21	0.16	63.8
Pagrus pagrus	farmed	0.87	0.77	307.0
	wild	0.22	0.21	83.1
Psetta maxima	farmed	0.41	0.36	143.3
	wild	0.36	0.32	126.1
Sciaena umbra	farmed	0.39	-	-
	wild	0.13	0.14	54.2
Seriola dumerili	farmed	1.70	1.35	540.9
	wild	0.89	0.78	312.4
Solea senegalensis	farmed	0.47	0.36	143.8
Solea solea	farmed	0.54	0.47	189.0
	wild	0.13	0.13	51.0
Umbrina cirrosa	wild	0.22	0.22	86.7

*Source : EFSA, 2010, http://www.efsa.europa.eu/en/press/news/nda100326.htm

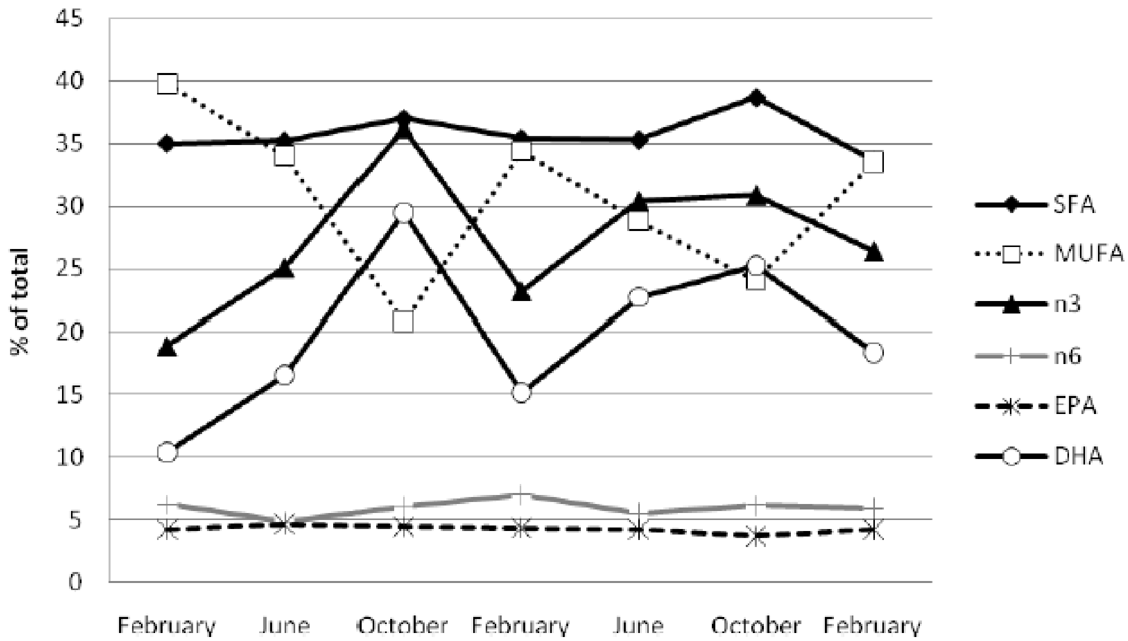

Fig. 1: Annual fluctuations of fatty acids (expressed in percentages of total fatty acids) in dentex *Dentex dentex* during growth. Data obtained from Chatzifotis et al. (2004)