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Original article

Determination of fatty acid composition in relation to the growth of meagre (*Argyrosomus regius*) cultured in net cages

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Abstract
The aim of this study was to determine the composition of fatty acids of meagre (*Argyrosomus regius*) produced in net cages at a private company in the Aegean Sea. Regular samples were taken over the study period by random sampling for the estimation of fatty acid contents. At the end of the study, the highest mean (± SD) fatty acids in fish flesh were recorded as oleic acid (26.46 ± 0.01%), linoleic acid (20.91 ± 0.01%) and palmitic acid (15.99 ± 0.01%). Mean (± SD) total saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acid values were determined as 26.17 ± 0.03%, 32.62 ± 0.03% and 31.24 ± 0.01% respectively. The total values of omega-3, omega-6, omega-9, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) were 8.73 ± 0.01 – 14.51 ± 0.04%, 18.78 ± 0.03 – 25.26 ± 0.01%, 27.12 ± 0.01 – 30.5 ± 0.01%, 1.39 ± 0.01 – 3.52 ± 0.01% and 4.24 ± 0.01 – 7.64 ± 0.01% respectively and all these values varied significantly over time ($P < 0.05$). Despite having a low crude fat content, the meagre could be a good source of PUFA, in terms of fatty acids.

Keywords: *Argyrosomus regius*; meagre; fatty acid; EPA; DHA

1 | INTRODUCTION

native to various Mediterranean species including *Dicentrarchus labrax*, *Sparus aurata*, *Dentex dentex* and *Diplodus* spp. in aquaculture and also an important species in terms of economy and meat quality. This species caught attention of the researchers in 1990s and its production was reported in France for the first time in 1997 (FAO 2019a). The production of this species was only a few tons at the beginning of the year 2000 and increased to 11770 tons in 2015 of which 5471 tons are being produced through aquaculture (FAO 2018; FAO 2019b). The meagre cultivation started a new era in aquaculture in which Turkey has become the world leader in 2016 (Anonymous 2018).

The meagre is at the forefront with high quality meat structure as well as many positive features including rapid growth, good feed conversion ratio and wide distribution area. Despite having low fat content it attracts the attention of consumers in a healthy and balanced nutrition model with high unsaturation of fatty acids. The fish, in general, contains high level of unsaturation fatty acids that varies with various factors including species, body size, cultivation areas, season and nutrition protocols (Shirai *et al.* 2001; Kalogeropoulos *et al.* 2004; Çaklı 2007).

There are other studies conducted with meagre focusing its aquaculture (Piccolo *et al.* 2008), pathology (Rigos and Katharios 2010), and meat quality (Poli *et al.* 2003; Hernandez *et al.* 2009). At the same time, most of the studies on fatty acid compositions of meagre was related to the effects of different sources of raw materials or the determination and comparison of wild species (Poli *et al.* 2003; Piccolo *et al.* 2008; Grigorakis *et al.* 2011; Martinez-Llores *et al.* 2011; Giogios *et al.* 2013; Martelli *et al.* 2013; Garcia Mesa *et al.* 2014; Sinanoglou *et al.* 2014; Saavedra *et al.* 2015; Emre *et al.* 2016; Lozano *et al.* 2017).

In the recent years, fish meat quality values have come into prominence for both consumers and producer. Among the meat quality values, especially in the seafood sector, fatty acids are the first concept that comes to mind after appearance and freshness. However, to the best of our knowledge, no studies are available about the fatty acids values of meagre in relation to their growth to date. Therefore, this study was aimed at the determination of fatty acid compositions of meagre from the first stocking in cage to the harvesting in the Aegean Sea.

2 | METHODOLOGY

This research was conducted in the open sea cage system of a commercial company located in Aydın province (Town Didim) in Aegean Sea of Turkey between September 2015 and November 2016. Meagre with an average weight of 8.22 ± 0.13 g were stocked in cages. Water temperature, dissolved oxygen (DO), salinity, and pH were measured monthly using the YSI multiparameter device. Feeds containing 48.2 – 51.8% protein and 16.3 – 16.4% lipid with sizes between 1.8 mm and 5 mm, produced by a commercial feed company were used in this study.

Fish samples were taken over specific periods (Period 1, September to November; Period 2, November to February; Period 3, February to April; Period 4, April to June; Period 5, June to September, and Final, September to November) using a random sampling method to represent the stock. The mean weights (± SD) of the fish sampled were 8.22 ± 0.13 g (initial), 50.23 ± 1.59 g (period 1), 141.46 ± 10.39 g (period 2), 153.48 ± 3.71 g (period 3), 214.79 ± 12.39 g (period 4), 314.95 ± 24.43 g (period 5) and 373.96 ± 15.65 g (final). Fish were killed with an overdose of an anesthetic substance (MS-222) and transported to the laboratory. After biometric measurements of fish samples, fish meat samples were stored in a deep freezer (WiseCryo/WUF-D500-80 °C) until biochemical and fatty acid analysis.

Crude fat was determined following standard procedures (AOAC 2000) using Soxhelet's method at the Faculty of Fisheries of Sinop University. Fatty acid analysis of fish meat was performed according to the IUPAC gas Hydrolysis method at TUBITAK Marmara Research Center Food Institute (Firestone and Horwitz 1979).

Statistical analyses were carried out using the software IBM SPSS 21. One-way ANOVA was used for mean comparison following a post-hoc test (Tukey's multiple comparison) with an α level of significance of 0.05.

3 | RESULTS AND DISCUSSION

Mean water temperature, DO, salinity and pH values were 20.06 ± 0.88 °C (range 15.66 – 25.70 °C), 9.34 ± 0.20 mgL^{-1} (range 8.77 – 9.91 mgL^{-1}), 35.56 ± 0.05 ‰ (range 34.77 – 35.70‰) and 8.43 ± 0.03 (range 8.31 – 8.55) respectively. These values are in the optimum range for meagre culture, have been reported that fish do not have a negative effect on growth and biochemical composition (Emre *et al.* 2016; El Kertaoui *et al.* 2017; Lozano *et al.* 2017).

Meagre with initial weight of 8.22 ± 0.13 g reached to 373.96 ± 15.65 g weight after 14 months. The crude fat values of fish meat were determined to be 1.89 ± 0.08% at the beginning and 3.19 ± 0.13% at the end of the study ($P < 0.05$) (see Baki *et al.* 2018 for details). Saavedra *et al.* (2015) reported that a positive relationship between fish size and crude fat content. In different studies, crude fat values of meagre varied from 0.4 – 2.5% (Poli *et al.* 2003; Piccolo *et al.* 2008; Chatzifotis *et al.* 2010; Giogios *et al.* 2013; Martelli *et al.* 2013; Garcia-Mesa *et al.* 2014; Sinanoglou *et al.* 2014; Rodriguez *et al.* 2017). Wang *et al.* (2014) reported that several factors including species age, environmental conditions (e.g. temperature and salinity), type and availability of food, feeding regimes, and season contribute to the differences in the crude fat value of fish. In this study, in all sampling periods, 28 different fatty acids were determined in total from C12:0 to C22:5n-3 in fish meat including 11 saturated fatty acids (SFA; Table 1), 6 monounsaturated fatty acids (MUFA; Table 2) and 11 polyunsaturated fatty acids (PUFA; Table 3).

The values of myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0), which are the most important representatives of saturated fatty acids, were varied from 2.0 ± 0.02 to 2.74 ± 0.01%, 15.36 ± 0.03 to 17.62 ± 0.02%, and 4.26 ± 0.02 to 5.09 ± 0.01% respectively, and differed significantly among periods ($p < 0.05$). These fatty acids were determined as 2.54 ± 0.01%, 15.99 ± 0.01% and 5.05 ± 0.01% respectively in the final samples.

During the study, the values of SFA were varied from 23.04 ± 0.07 – 26.87 ± 0.01% and differed significantly among periods ($P < 0.05$). The value of the SFA was 26.14 ± 0.03% in harvesting period that decreased from initial period. Comparing with the studies done previously on meagre, SFA values were found similar in most of the studies (e.g. Piccolo *et al.* 2008; Grigorakis *et al.* 2011; Giogios *et al.* 2013; Garcia Mesa *et al.* 2014) but a higher SFA value in wild (32.82%) and cultured (38.01%) fish was reported (Sinanoglou *et al.* 2014). However, Chaguri *et al.* (2017) reported that the amount of SFA in wild fish is higher than cultured fish. Saavedra *et al.* (2015) notified that the SFA value, which was affected by different harvest weighs, was between 28.6% and 29.7%. In a study investigating the effects of different sources of fat on meagre fatty acids, Emre *et al.* (2016) reported that SFA value was 35.28% and there was a negative correlation between the source of vegetable fat in the feed and the SFA value. Martinez-Llorens *et al.* (2011) reported that the amount of SFA from 22.9% to 30.2%, depending on the increase in crude fat content in feed. When all these studies were evaluated, it was considered that the difference in the SFA values were caused by the fish size and feed contents.

TABLE 1 Saturated fatty acids (SFA) of the meagre (%)

SFA	***Periods***						
	Initial	***1***	***2***	***3***	***4***	***5***	***Final***
C12:0	0.30±0.01^{c}	0.03±0.01^{a}	0.07±0.01^{b}	0.07±0.01^{b}	0.02±0.01^{a}	-	0.31±0.01^{c}
C13:0	0.01±0.01	-	-	-	-	-	0.01±0.01
C14:0	2.51±0.01^{c}	2.74±0.01^{d}	2.21±0.01^{b}	2.19±0.01^{b}	2.02±0.01^{a}	2.00±0.02^{a}	2.54±0.01^{c}
C15:0	0.38±0.01^{c}	0.45±0.01^{e}	0.42±0.01^{d}	0.41±0.01^{d}	0.33±0.01^{b}	0.30±0.01^{a}	0.37±0.01^{c}
C16:0	16.06±0.03^{b}	16.45±0.03^{d}	17.13±0.03^{e}	17.62±0.02^{f}	16.21±0.01^{c}	15.36±0.03^{a}	15.99±0.01^{b}
C17:0	0.35±0.01^{ab}	0.38±0.01^{bc}	0.42±0.01^{c}	0.42±0.01^{c}	0.34±0.02^{ab}	0.32±0.01^{a}	0.35±0.01^{ab}
C18:0	5.09±0.01^{e}	4.39±0.01^{b}	4.35±0.01^{b}	4.60±0.01^{d}	4.48±0.01^{c}	4.26±0.02^{a}	5.05±0.01^{e}
C20:0	0.47±0.01^{d}	0.40±0.01^{c}	0.27±0.01^{a}	0.29±0.01^{a}	0.28±0.01^{a}	0.32±0.01^{b}	0.49±0.01^{d}
C22:0	0.30±0.01^{c}	0.28±0.01^{bc}	0.16±0.01^{a}	0.16±0.01^{a}	0.19±0.01^{a}	0.19±0.01^{a}	0.25±0.01^{b}
C23:0	0.05±0.01^{bc}	0.02±0.01^{a}	-	0.03±0.01^{ab}	0.15±0.01^{d}	0.17±0.01^{d}	0.05±0.01^{c}
C24:0	0.17±0.02^{de}	0.13±0.01^{cd}	0.12±0.01^{bc}	0.10±0.01^{abc}	0.07±0.01^{a}	0.09±0.01^{ab}	0.18±0.01^{e}
SFA	26.87±0.01^{f}	25.31±0.03^{c}	25.14±0.05^{c}	25.86±0.04^{d}	24.13±0.07^{b}	23.04±0.07^{a}	26.14±0.03^{e}

Values are mean ± SE and in rows marked with different letters are significantly different (P < 0.05).

TABLE 2 Monounsaturated fatty acids (MUFA) of meagre (%)

MUFA	***Periods***						
	Initial	***1***	***2***	***3***	***4***	***5***	***Final***
C14:1	0.02±0.01	-	0.02±0.01	0.02±0.01	-	-	-
C16:1	2.95±0.01^{a}	3.76±0.01^{c}	3.83±0.01^{c}	3.91±0.01^{c}	3.39±0.07^{b}	2.97±0.01^{a}	2.86±0.01^{a}
C18:1n9c	26.78±0.05^{ab}	25.66±0.01^{ab}	25.23±0.01^{a}	25.98±0.03^{ab}	26.04±1.40^{ab}	28.61±0.02^{b}	26.46±0.01^{ab}
C20:1n9c	2.19±0.01^{d}	1.63±0.02^{b}	1.41±0.01^{a}	1.39±0.01^{a}	1.68±0.01^{b}	1.97±0.02^{c}	2.23±0.01^{d}
C22:1n9	0.40±0.01^{b}	0.30±0.01^{a}	0.48±0.01^{d}	0.32±0.01^{a}	-	-	0.43±0.01^{c}
C24:1	0.63±0.01^{cd}	0.66±0.01^{d}	0.55±0.01^{bc}	0.53±0.03^{b}	0.32±0.01^{a}	0.31±0.02^{a}	0.66±0.01^{d}
MUFA	32.97±0.07	32.04±0.01	31.52±0.02	32.15±0.01	31.45±1.48	33.87±0.02	32.62±0.03

Values are mean ± SE and in rows marked with different letters are significantly different (P < 0.05).

The amounts of oleic acid (C18:1n9c), the most important representative of monounsaturated fatty acids and omega-9 fatty acids, were varied from 25.23 ± 0.01% to 28.61 ± 0.02% and it differed significantly over time ($p < 0.05$). The high amount of oleic acid in aquacultured fish species was confirmed for meagre (Poli *et al.* 2003) and other Mediterranean cultured species (Grigorakis *et al.* 2002; Orban *et al.* 2003; Özden and Erkan 2008; Alvarez *et al.* 2009). This fatty acid accumulation may either be a result of source of vegetable oil in the diet. Palmitoleic acid (C16:1) values were the highest in the period-3 period (3.91 ± 0.01%) and the lowest in the final period (2.86 ± 0.01%).

During the study, MUFA values of fish meat were varied between 31.45 ± 1.48% and 33.87 ± 0.02% ($P < 0.05$). The mean value of the MUFA was 32.62 ± 0.03% at the harvesting period and this value was a decrease from the initial period. In previous studies conducted with meagre, MUFA values were found lower in wild fish than that of cultured fish (Sinanoglou *et al.* 2014; Chaguri *et al.* 2017). In the culture meagres, it was reported that the sources of raw materials can affect the MUFA values (Grigorakis *et al.* 2011; Emre et al. 2016; Lozano *et al.* 2017). Apart from this, fish body size can also affect the MUFA values (Martelli *et al.* 2013; Saavedra *et al.* 2015).

The linoleic acid values (C18:2n6) of meagre were determined to be lowest in the first period (17.95 ± 0.04%) and the highest at period 5 (24.82 ± 0.01%; $P < 0.05$). High levels of linoleic acid in cultured fish may be due to vegetable oils in feed (Grigorakis *et al.* 2002; Benedito-Palos et al. 2009), whereas many wild fish species have very low contents of this kind of fatty acid (Kalogeropoulos *et al.* 2004; Alvarez *et al.* 2009). Similar observations were also confirmed in several Mediterranean aquacultured species (e.g. *Sparus aurata*, *Dicentrarchus labrax*, *Dentex dentex*) (Grigorakis 2007; Özden and Erkan, 2008), including meagre (Poli *et al.* 2003). In the study, α-linolenic acid (C18:3n3) and γ-linoleic acid (C18:3n6) values were varied from 1.90 ± 0.01 – 3.47 ± 0.01% and 0.06 ± 0.01 – 0.21 ± 0.01% respectively ($P < 0.05$). The arachidonic acid values (C20:4n-6) were the highest at period 1 (0.61 ± 0.01%) and lowest in the period 5 (0.28 ± 0.01%) and varied significantly among the periods ($P < 0.05$).

The PUFA values were varied from 31.24 ± 0.01% to 37.14 ± 0.16% and showed fluctuations among periods ($P < 0.05$). The minimum value (31.24±0.01%) was recorded during harvesting period. However, a negative relationship between crude fat and PUFA values has been reported earlier (Baki *et al.* 2018). Negative relationship between body size and PUFA values was also reported in the same study that is in accordance with Saavedra *et al.* (2015). Chaguri *et al.* (2017) reported that the PUFA values of meagres of 600 g and 1500 g body weight were 37% and 34.51% respectively. The PUFA values obtained in the present study were similar to the other studies (e.g. Costa *et al.* 2013; Garcia Mesa *et al.* 2014; Emre *et al.* 2016; Lozano *et al.* 2017).

The omega-3 series PUFA docosahexaenoic acid (DHA C22:6n-3) and eicosapentaenoic acid (EPA C20:5n-3), and the n-6 series PUFA arachidonic acid (C20:4n-6), play very important roles in marine fish development (Izquierdo and Koven 2011). In this study EPA and DHA values were varied from 1.39 ± 0.01 to 3.52 ± 0.01% and 4.24 ± 0.01 to 7.64 ± 0.01% respectively (Figure 1). The both values differed significantly over periods ($P < 0.05$). The EPA and DHA values recorded in this study is in accordance with the existing literature on meagre (e.g. Grigorakis *et al.* 2011; Giogios *et al.* 2013; Costa *et al.* 2013; Garcia-Mesa *et al.* 2014; Sinanoglou *et al.* 2014; Saavedra *et al.* 2015; Emre *et al.* 2016; Fountoulaki *et al.* 2017; Lozano *et al.* 2017). Saavedra *et al.* (2017) reported that the EPA and DHA values were 3.3% and 7.51% in the large meagre weighing 3.8 kg. However, Martelli *et al.* (2013) reported that the harvesting period can affect the EPA and DHA values and these values decrease as fish size increased. Garcia-Mesa *et al.* (2014) reported that EPA value of meagre was similar to the values in the diets, while DHA values of meagre were increased twice as much as feeds. It was explained that this situation could be accompanied by a conversion from EPA to DHA when the dietary supply of DHA was insufficient to meet the fish metabolic requirements.

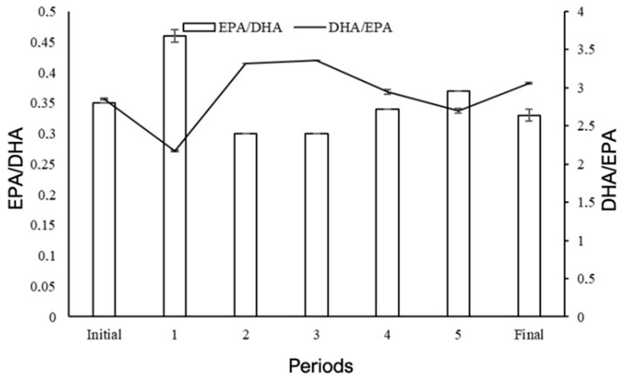

FIGURE 1 EPA/DHA and DHA/EPA values of meagre

In the present study, omega-3, omega-6 and omega-9 values were varied from 8.73 ± 0.01 – 12.96 ± 0.03%, 18.78 ± 0.03 – 25.26 ± 0.01% and 27.12 ± 0.01 –30.58 ± 0.01% respectively (Figure 2) and the statistical difference between periods were significant ($P < 0.05$). Omega-3 values recorded in this study were found lower than other studies with meagre (Piccolo *et al.* 2008; Grigorakis *et al.* 2011; Giogios *et al.* 2013; Sinanoglou *et al.* 2014; Saavedra *et al.* 2015, 2017; Chaguri *et al.* 2017). However, the omega-3 values of meagre were similar to other aquacultured species, such as sea bass and sea bream (Ibeas *et al.* 1997; Lenas *et al.* 2011; Baki *et al.* 2015). In studies with cultured fish, omega-6 values have been reported higher than omega-3 due to the sources of vegetable raw materials added to the diet during feed preparation (Piccolo *et al.* 2008; Benedito-Palos *et al.* 2009; Costa *et al.* 2013). Total omega-9 fatty acid in fish meat was higher than the sum of other omega fatty acids and this value was similar to Omega-9 value (%29.6) of meagre reported by Grigorakis *et al.* (2011).

In the present study, omega-3/omega-6 and omega-6/omega-3 ratios of meagre were varied between 0.41 ± 0.01 – 0.77 ± 0.01 and 1.30 ± 0.01 – 2.47 ± 0.01 respectively ($P < 0.05$) (Figure 3).

Chaguri *et al.* (2017) reported that omega-3/omega-6 ratio of wild and cultured meagre was varied from 3.55–4.76 and 2.18–1.94 respectively which is higher than the ratio determined in this study. Studies have also showed a higher omega-3/omega-6 ratio in farmed meagre than wild fish lipids (Hossain 2011; Sinanoglou *et al.* 2014). Different omega-3/omega-6 ratios were reported in studies with aquacultured meagre ranging from 0.77 to 1.94 (Piccolo *et al.* 2008; Grigorakis *et al.* 2011; Costa *et al.* 2013; Sinanoglou *et al.* 2014). Generally this ratio has been reported lower in fishes fed with diets containing vegetable oil than those feed on oil-based diets (Trushenski *et al.* 2011; Emre *et al.* 2016).

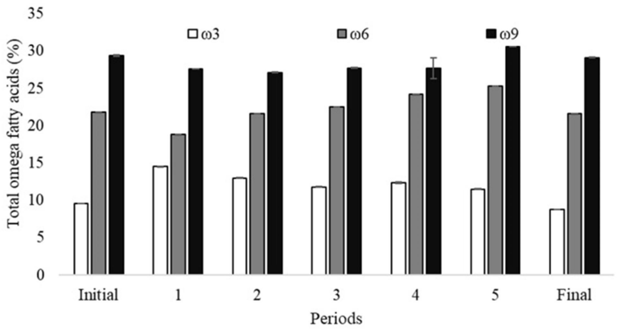

FIGURE 2 Omega-3, omega-6 and omega-9 values in meagre over different study periods

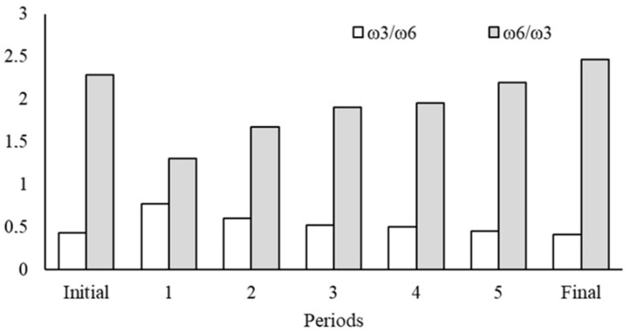

FIGURE 3 Omega-3/Omega-6 and Omega-6/Omega-3 ratios in meagre over study periods

Fatty acid profile of fish can vary depending on dietary lipid sources, season, water temperature, salinity and some other factors (Codier *et al.* 2002; Saavedra *et al.* 2017). At the end of the study, palmitic, oleic and linoleic acid in meagre was determined as 63% of the total fatty acid composition. Higher concentrations of oleic and linoleic acid in meagre are attributed to use of vegetable oils in feed (Nasopoulou and Zabetakis 2007; Pickova and Morkoro 2007). Few fishes such as meagre sold in portion size (400–700g) as they are not considered very suitable for marketing due to large head and bones, low amount of flesh and less taste and generally fish weighing more than 2 kg has demand in global market (Monfort 2010; Ribeiro *et al.* 2013). In present study, total fat content of the edible parts (muscle) of the farmed meagre was determined to be rich in fatty acids. However, fatty acid content may vary depending on the age of meagre as seen over the study period that could be due to feed quality and sources of raw materials used as feed ingredients. This species is a good source of PUFA when compared to other marine and aquaculture species.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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