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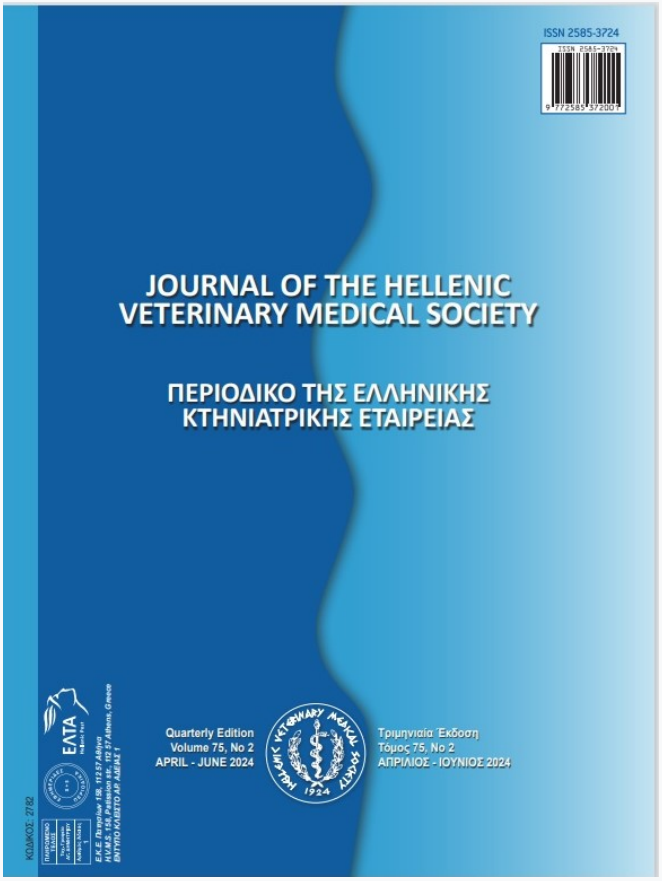

Comparison of growth, carcass and meat quality characteristics of triploid and diploid Black Sea trout (Salmo trutta labrax) under laboratory conditions

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Research article
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Comparison of growth, carcass and meat quality characteristics of triploid and diploid Black Sea trout (*Salmo trutta labrax*) under laboratory conditions

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ABSTRACT: This study compared the growth performance of triploid and diploid Black Sea trout (*Salmo trutta labrax*) during their fry (initial weight 0.21 - 0.21 g), fingerling (1.97 - 2.08 g) and juvenile (52.15 - 57.81 g) stages. The carcass ratio, gonadosomatic index (GSI), hepatosomatic index (HSI), proximate, and fatty acid composition for the juvenile fish were also investigated. The results evinced no metabolic advantage resulting from triploidy before sexual maturation of Black Sea trout as the triploid growth was equal to diploid siblings. The juvenile triploid Black Sea trout grew faster than diploid having significantly higher weight gain, length increment, thermal growth coefficient, specific growth rate, and lower feed conversion ratio. The GSI values tended to increase over time in diploid and their significantly lower values were observed in triploid in the last three months of the trial. The HSI of triploids was significantly higher than diploid siblings. Triploid had significantly higher fat contents, and possessed higher levels of saturated and monounsaturated fatty acids than diploid. Diploid had higher polyunsaturated fatty acids than triploid siblings. These findings indicate the potential for superior triploid growth with better carcass ratio suggesting a great benefit of induced triploidy in Black Sea trout culture.

Keywords: *Fatty acid profiles; Growth; Induced triploidy; Proximate analysis; Salmonidae*

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INTRODUCTION

Polyploidy induction is an artificial way for producing non-maturing populations of farmed fish with the intent of optimizing their somatic growth with lower food conversion and a greater percentage of edible carcass weight (Poontawee et al., 2007; Tiwary et al., 2004). Furthermore, the use of sterile triploid fish in culture has been recommended by many to minimize the potential genetic and ecological risks associated with fish escapes from cage-culture with wild populations (ICES, 1991; NASCO, 1991; Taylor et al., 2012).

Polyploidy has been artificially induced through traumatic interference with newly fertilized eggs by either sub-lethal temperature treatments (cold or heat shock) or through hydrostatic pressure application (Akhan et al., 2011; Piferrer et al., 2009; Tiwary et al., 2004). Information regarding the performance of triploid and diploid fish is contradictory. For example, several studies have reported a poor growth rate of triploid (Cassani and Caton, 1986; Galbreath et al., 1994; McGeachy et al., 1995; Sacobie et al., 2015) equal to (Hussain et al., 1995; Kim et al., 1994; McGeachy et al., 1996) or even better (Purdom, 1976; Thorgaard and Gall, 1979; Wolters et al., 1982) than their diploid siblings. The potential benefits and performance of induced triploidy require a species-specific base assessment since several studies find a greater variability of triploids performance both within and between families (Bonnet et al., 1999; Oppedal et al., 2003; Taylor et al., 2012). According to Taylor et al. (2012) triploids have also often been associated with a wide range of morphological deformities such as spinal deformity, lower jaw deformity, gill filament deformity syndrome, and reduced gill surface area. Also, they are less resilient to chronic stress (Benfey, 1999; Maxime, 2008; Fraser et al., 2012).

Black Sea trout (*Salmo trutta labrax*) is an opportunist ecotype native to the Eastern Black Sea coast and rivers (Aksungur et al., 2011; Balta et al., 2017; Başçınar and Başçınar, 2008; Başçınar et al., 2005). It is an anadromous salmonid species known to lack true smoltification unlike salmon (Aksungur et al., 2011). It moves to inshore brackish water under favourable conditions, and pass to freshwater frequently without waiting until general maturity unlike salmon (Aksungur et al., 2011; Okumuş et al., 2006). *Salmo sp.* has been recognized as a new culture species for intensive aquaculture in Turkey with 1302 tonnes of production in 2022 (TURKSTAT, 2023).

This study aims to compare the performance of triploid Black Sea trout relative to their diploid siblings with the perspective of improving fish farming. The present study assessed the growth performance of triploid and diploid from fry through maturing (juvenile) Black Sea trout. Also, the carcass ratio, meat yield, proximate composition, and fatty acid profile of triploid and diploid Black Sea trout (for juvenile fish only) were compared to determine any effects of polyploidy on them.

MATERIALS AND METHODS

Acquisition of diploid and triploid Black Sea trout

The experimental fish were provided by the trout hatchery through the Faculty of Marine Sciences, Karadeniz Technical University. The hatchery strain diploid Black Sea trout were produced by a procedure similar to that used by Başçınar et al., (2010). For the production of triploid fish, they immersed the fertilized eggs (following 10-min post-fertilization) in a water-bath (10 l) at shock temperature of 28 ºC with an exposure time of 10 min. Further details (including triploidy confirmation tests) are provided in Delihasan Sonay (2013).

Growth experiments

Three growth experiments were conducted to compare the growth performances of triploid and diploid Black Sea trout during their fry, fingerling, and juvenile stages. A total of 180 fry (ranging 0.21 - 0.21 g, 1 month post hatched), 180 fingerlings (ranging 1.97 - 2.08 g, 4 months old) and 180 juvenile (ranging from 52.15 - 57.81 g, +1-year-old) Black Sea trout were used in this study. Each group had 50% diploid and 50% triploid fish. The diploid and triploid in each group were further subdivided into three subgroups/replicates (1/3 of the total number of total fish per replica), and each subgroup had either diploid or triploid fish. Each subgroup of fry was stocked into a fiberglass aquarium (~10 L), fingerlings into a small tank (~100 L) and juvenile fish into a tank with ~250 L water volume. Each of them had a continuous supply of freshwater and a bubble aeration system to ensure oxygen saturation. The water temperature was recorded daily (Figure 1). Triploid and diploid fish were held in separate freshwater tanks for each growth experiment.

The chemical composition of commercial pellets used in the present study is given in Table 1. The fry fish were handfed four times a day, while fingerling

and juvenile fish were fed three times a day. After each feeding, the uneaten pellets from each tank (as well as the aquarium) were recovered and dried in an oven to calculate the amount of meal consumed by each subgroup (Başçınar et al., 2010). The growth experiments were carried out for a duration 90 days for the fry fish and 150 days for the fingerling and juvenile fish.

Fish in each subgroup were individually weighed every 15 days of the growth trial. Also, the total length (*TL*) of each fish was measured. Their growth performances were assessed using the following equations:

Thermal-unit growth coefficient:

$$TGC = [(W_f^{1/3} - W_i^{1/3}) / (temp.(°C) \times t)] \times 100 \quad (1)$$

Specific growth rate:

$$SGR = [(ln(W_f) - ln(W_i) / t] \times 100 \quad (2)$$

Condition factor:

$$CF = (W / TL^3) \times 100 \quad (3)$$

Feed conversion rate

$$FCR = Feed\ eaten\ by\ fish / Weight\ gained\ by\ fish \quad (4)$$

where W_f is final and W_i is the initial weight, t is time (days) between W_f and W_i, TL is total length of a fish.

Meat yield and chemical composition

Additional 120 juvenile fish (60 fish per diploid and triploid groups) were taken for the evaluation of carcass ratio, proximate composition, and fatty acid analysis. They were reared in parallel to the juvenile Black Sea trout assigned for the growth experiments, and were stocked in two separate holding tanks having a continuous supply of freshwater with a bubble aeration system.

Carcass Ratio and Meat Yield

Ten juvenile fish per genetic group were randomly selected after every 30 days for processing. The total length and weight of each fish was measured, and the fins were separated following beheading of fish together with gills. The fish was eviscerated by hand and the ventral part was sheared, filleted and skin from the edible muscle was removed. Consequently, the data collected for each fish included fish total weight (*Wf*), carcass weight (*Cw*), head weight, gonads weight (*Wg*), and liver weight (*WL*) (Bosworth et al., 2004; Şahin et al., 2011). An electronic digital balance (XB4200C, Presica, Switzerland) was used to measure the weights.

The gonadosomatic index (GSI) and hepatosomatic index (HSI) were determined as:

$$GSI = 100 \times (W_g / W_f) \quad (5)$$

$$HSI = 100 \times (W_L / W_f) \quad (6)$$

Proximate Compositions

The dry matter, total protein, total fat and ash contents were analysed from a homogenized sample of muscle prepared by using a meat chopper (grinder) (Arçelik, K-1631 P Valso Plus, 2.2 L capacity, Türkiye). Up to 5 g of this homogenized sample (per genetic group) was kept in frozen storage at -40° C for fatty acid profile analysis. All analyses were performed in triplicate for such parameters. The AOAC (1995) standard reference method 985.14 was used for determining the dry matter, the AOAC (1980) method 7.009 for ash, the AOAC (1980) method 2.507 for total protein contents. Further details about these methods are provided in Şahin et al., (2011), Çağlak et al., (2017), Tufan et al., (2018), Papachristou et al., (2021) and Karslı et al., (2021) . The total fat contents were determined by using a solvent extractor Velp SER 148/6 (Velp Scientifica, Milano, Italy) with petroleum ether (130° C) as a solvent. The moisture contents were determined from 2 g of fish muscle drying at 105° C for 24 hrs in the oven.

Fatty Acid Analysis (Analysis of fatty acid methyl esters (FAME%))

The samples that had been previously frozen at -40° C were defrosted at 4° C for 10 hrs prior to fatty acid analysis (Tufan et al., 2018). The chloroform: methanol (2:1, v/v) method of Bligh and Dyer (1959) was used to extract fat. The fatty acid composition was then determined using gas chromatography (Shimadzu 2010) equipped with an autosampler (Shimadzu, JAPAN), a split injector (ratio 1:20), and a flame ionization detector (FID), in adherence to the procedure described in Şahin et al., (2011) and Tufan et al. (2018). The fatty acid composition of the commercial pellets used to feed juvenile fish was also determined through the same procedure (Table 4). Three replicate gas chromatography analyses were performed for each sample extract, and the results are expressed in gas chromatography area % as mean values and the standard deviation (SD).

Statistical Analysis

The Sigma Plot 11.0 statistical program (SYSTAT Software, Inc., San Jose, CA, USA) and Microsoft Office Excel® software package program were used to evaluate the data. The normal distribution of all data was tested using the Shapiro-Wilk test. The data was analysed using one-way ANOVA, and differences between groups were determined using Tukey's post-hoc test ($p<0.05$).

RESULTS

Growth performance

The data about the growth performances of fry, fingerling, and juvenile Black Sea trout are presented in Figure 2, 3, and 4. There was no significant variation in the growth performance of triploid and diploid Black Sea trout fry at the end of the growth experiment period. The triploid fingerling fish had significantly higher final mean weight, TGC, and CF than diploid, and showed no significant differences for final total length, SGR, and FCR. Final weight, final length, TGC, and SGR were significantly higher in triploid juvenile fish than diploid siblings (Table 2). Furthermore, the triploid juvenile fish had significantly lower FCR than diploid siblings.

Head and carcass ratios

The head ratio to the total body weight of triploid ranged from 9.6 ± 0.9 to 12.8 ± 1.5, which was relatively lower than diploid siblings. The percentage carcass ratio of triploid juvenile fish to total body weight ranged from 74.6 ± 1.2 to 80.1 ± 8.9, and from 65.0 ± 13.5 to 76.4 ± 1.6 for diploid. The carcass ratios of triploid and diploid Black Sea trout were found significant differences in the last four months of the growth experiments.

GSI and HSI

The GSI of triploid was smaller than diploid siblings, and showed significant differences in the last three months of the growth experiments. Their HSI was significantly higher than the diploid siblings (Table 3).

Carcass proximate composition

The data about the moisture contents, dry matter, total protein, total fat and ash contents for triploid and diploid juvenile fish are provided in Table 3. In the majority of cases, no significant differences were observed in the moisture contents, dry matter, total protein and ash contents of triploid and diploid. However, their total fat contents differed significantly throughout the study and the highest values of total fat contents were recorded for triploid fish.

Fatty acid methyl esters (FAME%)

Table 4 represents the fatty acid profile of triploid and diploid juvenile fish as FAME%. The highest value of ΣSFA was found for triploid as 24.19% (± 0.15) in July and for diploid as 23.62% (± 0.23) in June. The ΣSFA of triploid and diploid juvenile fish showed no significant differences during June, August, October and November. Their ∑MUFA also showed no significant variation during June, July, October and November. The highest ∑MUFA was observed in triploid juvenile fish during August and September which significantly differed from diploid siblings. Also, ∑PUFA contents of triploid and diploid did not show significant differences throughout the study except in August. The highest ∑PUFA contents was recorded for diploid juvenile fish in August, which differed significantly from the ∑PUFA contents of triploid siblings. With regards to EPA+DHA, their highest values were recorded in diploid fish during August and September ($p<0.05$). Furthermore, the ∑n3/∑n6 ratio of triploid and diploid juvenile fish showed no significant differences throughout this study. The ∑n6/∑n3 ratio of triploid and diploid juvenile fish also did not show significant differences except in September where triploid fish had the highest value of ∑n6/∑n3 than diploid siblings.

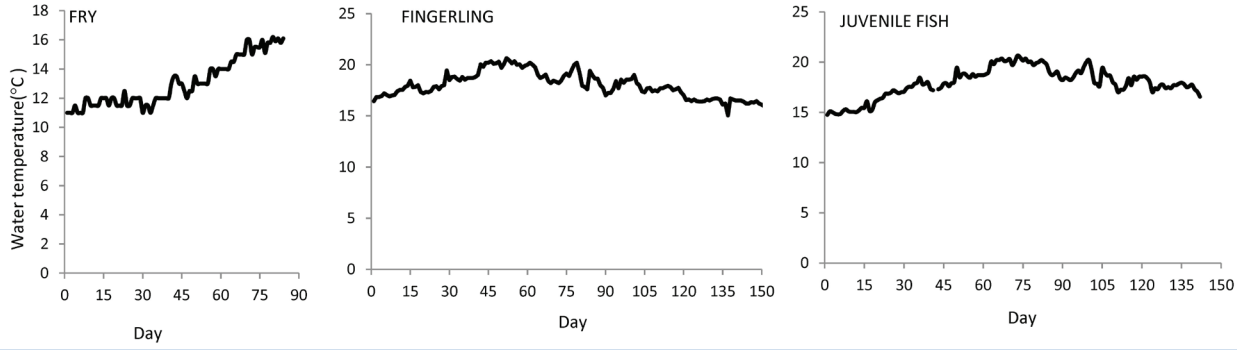

Figure 1: The water temperature profile over the studied period present as mean ± S.D.

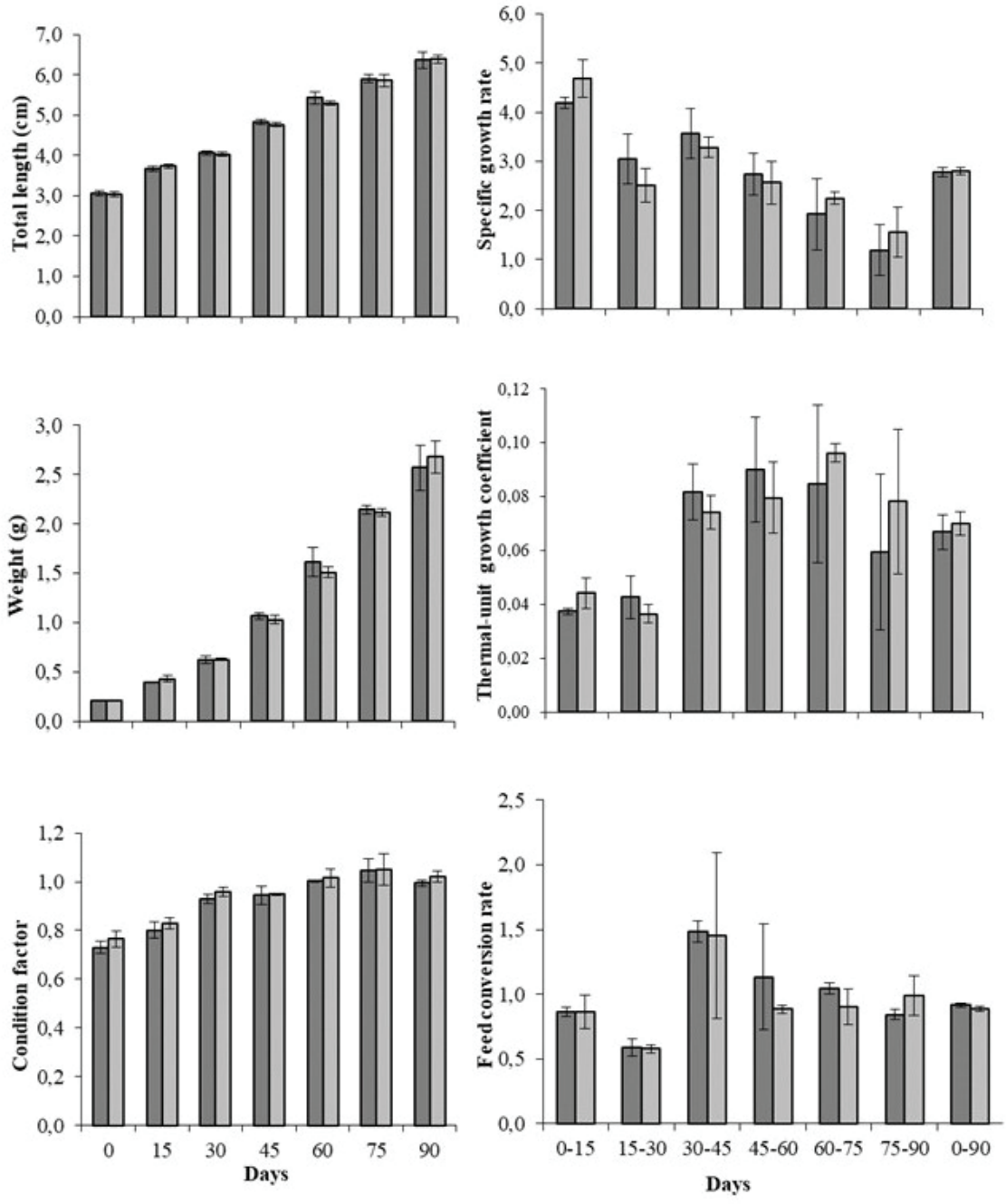

Figure 2: Mean (± S.D.) values of live body weight, total length, feed conversion rate (FCR), specific growth rate (SGR), thermal-unit growth coefficient (TGC) and condition factor (CF) of fry triploid (■) and diploid (■) black sea trout *Salmo trutta labrax*

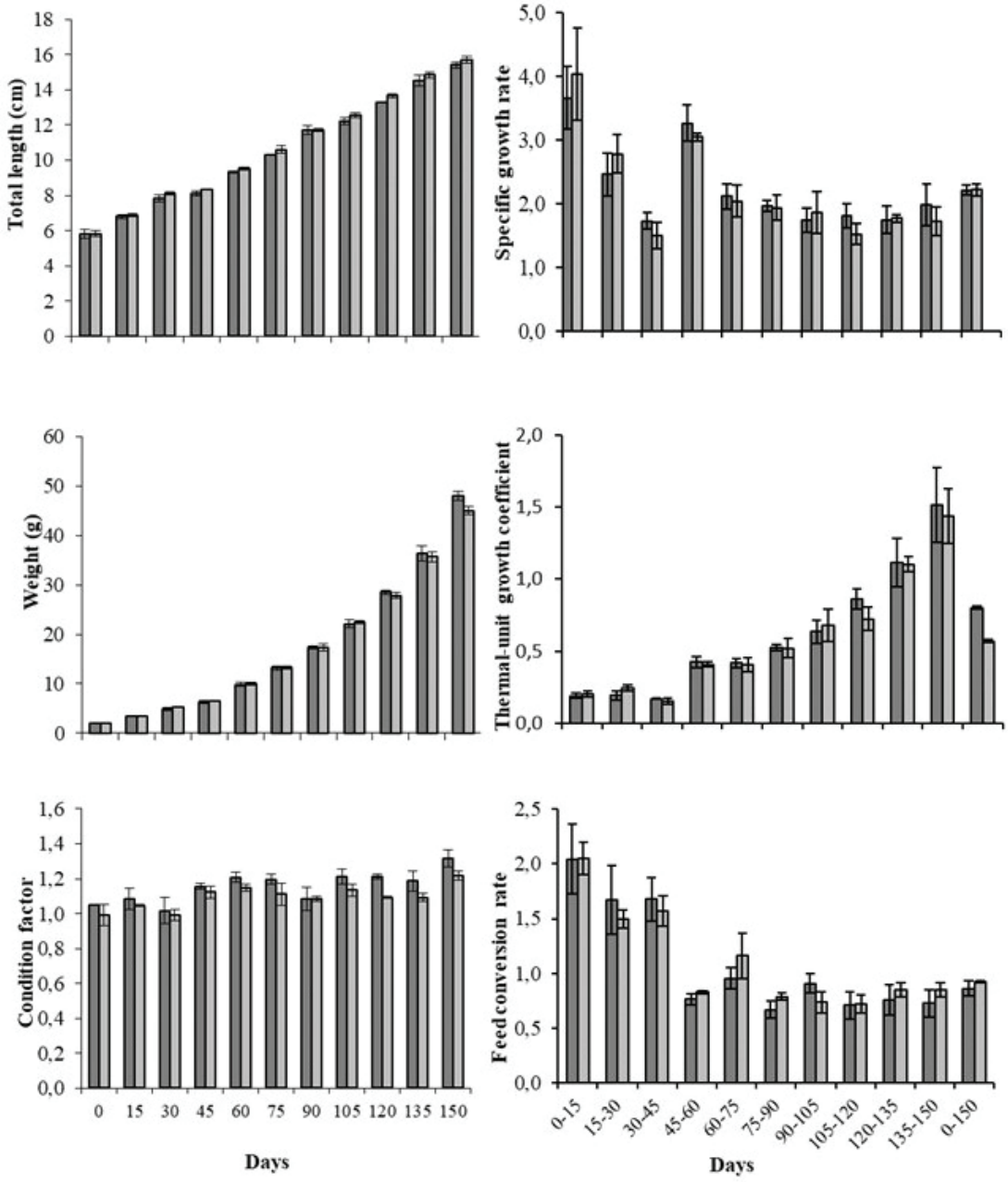

Figure 3: Mean (± S.D.) values of live body weight, total length, feed conversion rate (FCR), specific growth rate (SGR), thermal-unit growth coefficient (TGC) and condition factor (CF) of fingerling triploid (■) and diploid (■) black sea trout *Salmo trutta labrax*.

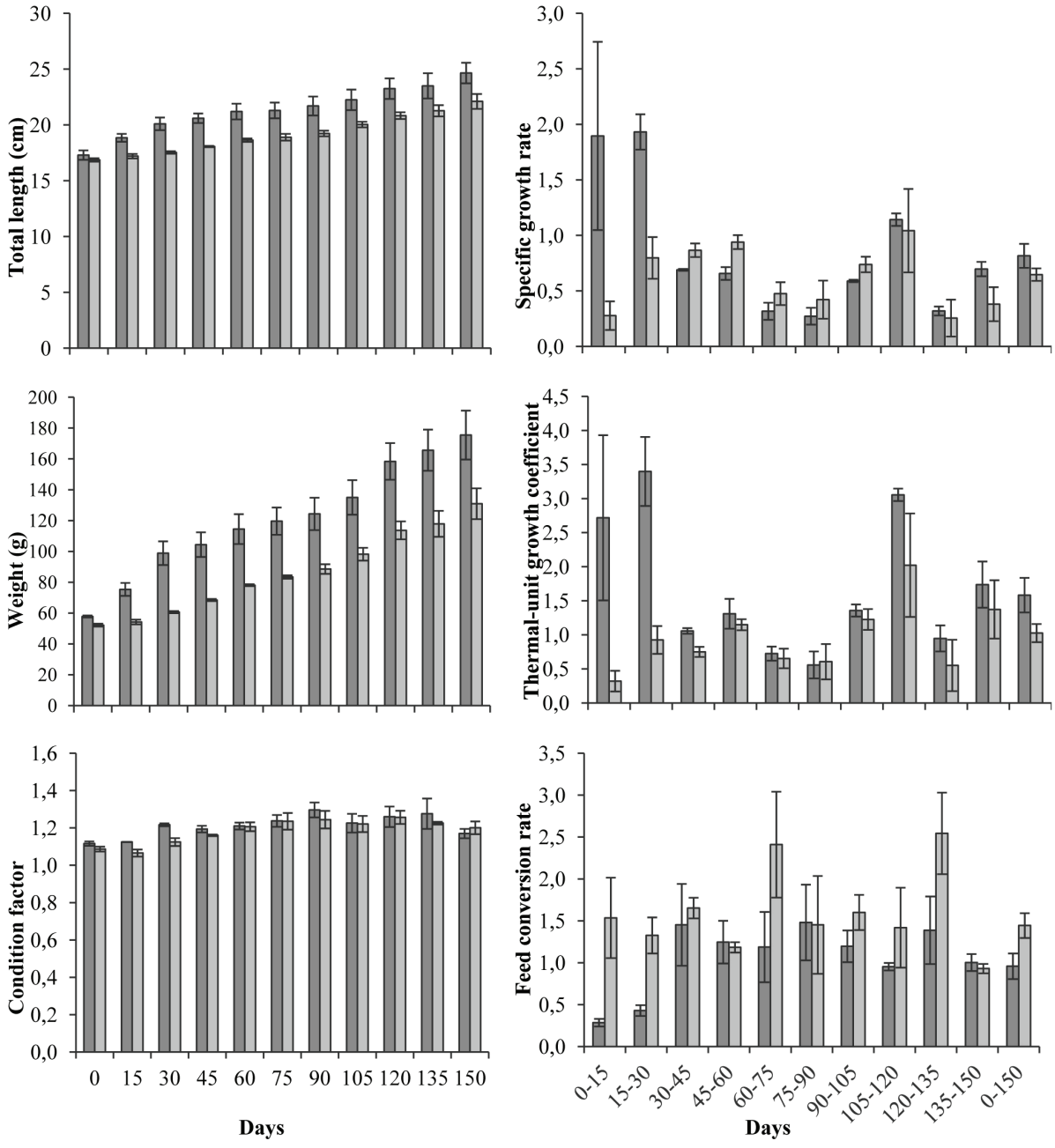

Figure 4: Mean (± S.D.) values of live body weight, total length, feed conversion rate (FCR), specific growth rate (SGR), thermal-unit growth coefficient (TGC) and condition factor (CF) of juvenile triploid (■) and diploid (■) black sea trout *Salmo trutta labrax*.

Table 1: Main ingredients of commercial pellets fed to diploid and triploid Black Sea trout *Salmo trutta labrax*

Ingredient (%)	Fry feed	Fingerling feed	*Juvenile fish feed
Crude protein	55.0	50.0	44.0
Crude fat	10.0	18.0	18.0
Fibre	1.3	2.5	3.5
Ash	11.0	10.0	10.0
Moisture	12.0	10.0	10.0

*Fatty acid profile is given in Table 4

Table 2: Mean (± S.D.) values of thermal-unit growth coefficient (TGC), specific growth rate (SGR), condition factor (CF) and feed conversion rate (FCR) for triploid and diploid siblings of Black Sea trout (*Salmo trutta labrax*) fed on commercial pellets.

	FRY		FINGERLING		JUVENILE FISH	
PARAMETER	Triploid	Diploid	Triploid	Diploid	Triploid	Diploid
Wi (g)	0.21 ± 0.01	0.21 ± 0.01	2.08 ± 0.02	1.97 ± 0.03	57.81 ± 0.64	52.15 ± 0.94
Wf (g)	2.57 ± 0.23	2.68 ± 0.16	48.00 ± 0.86^{A}	45.05 ± 0.09^{A}	175.46 ± 15.85^{B}	130.90 ± 10.02^{B}
Li (cm)	3.07 ± 0.06	3.03 ± 0.06	5.83 ± 0.25	5.83 ± 0.15	17.30 ± 0.42	16.87 ± 0.15
Lf (cm)	6.37 ± 0.21	6.40 ± 0.10	15.40 ± 0.18	15.69 ± 0.19	24.65 ± 0.92^{B}	22.17 ± 0.67^{B}
TGC	0.07 ± 0.01	0.07 ± 0.01	0.80 ± 0.01^{A}	0.57 ± 0.01^{A}	1.58 ± 0.18^{B}	1.03 ± 0.13^{B}
SGR	2.78 ± 0.09	2.81 ± 0.07	2.21 ± 0.08	2.22 ± 0.09	0.82 ± 0.06^{B}	0.65 ± 0.06^{B}
CF	0.99 ± 0.01	1.02 ± 0.02	1.32 ± 0.05^{A}	1.22 ± 0.03^{A}	1.17 ± 0.03	1.20 ± 0.03
FCR	0.92 ± 0.01	0.89 ± 0.02	0.86 ± 0.07	0.92 ± 0.01	0.96 ± 0.15^{B}	1.45 ± 0.15^{B}

The subscript uppercase letters (A for fingerling, B for juvenile fish) in the same row represent significant differences between triploid and diploid for the same group ($p<0.05$). Wi; initial weight, Wf; final weight, Li; initial length, Lf; final length

Table 3: Mean (± S.D.) values of head weight (%), carcass ratio (%), proximate composition of carcass, gonadosomatic index (GSI) and hepatosomatic index (HSI) of triploid and diploid siblings of Black Sea trout (*Salmo trutta labrax*) fed on commercial pellets.

				PROXIMATE COMPOSITION						
Month		Head weight (%)	Carcass ratio (%)	Moisture (%)	Dry matter (%)	Protein (%)	Fat (%)	Ash (%)	GSI (%)	HSI (%)
June	Triploid	10.17 ± 0.72^{A}	76.84 ± 1.64^{A}	76.38 ± 0.23	23.62 ± 0.23	18.53 ± 0.14^{A}	3.50 ± 0.07^{A}	1.52 ± 0.02	0.16 ± 0.09	1.17 ± 0.14
	Diploid	13.03 ± 1.11^{A}	73.26 ± 1.93^{A}	75.92 ± 0.41	24.07 ± 0.41	20.53 ± 0.11^{A}	2.59 ± 0.05^{A}	1.64 ± 0.06	0.13 ± 0.12	1.22 ± 0.20
July	Triploid	9.64 ± 0.88^{B}	76.92 ± 1.06	73.64 ± 0.32^{B}	25.66 ± 0.66	19.50 ± 0.57	4.79 ± 0.14^{B}	1.58 ± 0.05	0.17 ± 0.20	1.32 ± 0.20^{B}
	Diploid	12.28 ± 1.06^{B}	76.44 ± 1.61	76.59 ± 0.77^{B}	23.41 ± 0.77	18.03 ± 0.47	2.77 ± 0.10^{B}	1.66 ± 0.35	0.14 ± 0.10	1.03 ± 0.24^{B}
August	Triploid	10.93 ± 0.81	76.71 ± 9.19^{C}	78.91 ± 0.25	21.06 ± 0.25	17.59 ± 0.96	3.00 ± 0.23^{C}	1.29 ± 0.01^{C}	0.13 ± 0.10	1.76 ± 0.17^{C}
	Diploid	11.80 ± 2.37	64.98 ± 13.53^{C}	77.93 ± 0.21	22.08 ± 0.21	18.61 ± 0.54	2.25 ± 0.03^{C}	1.57 ± 0.01^{C}	0.17 ± 0.10	1.20 ± 0.12^{C}
September	Triploid	10.93 ± 0.77^{D}	74.57 ± 1.23^{D}	76.87 ± 0.27	23.13 ± 0.27	19.28 ± 0.29	3.81 ± 0.12^{D}	1.41 ± 0.00	0.18 ± 0.09^{D}	1.88 ± 0.20^{D}
	Diploid	12.31 ± 1.09^{D}	72.39 ± 1.60^{D}	77.68 ± 0.25	22.32 ± 0.25	20.40 ± 0.44	2.11 ± 0.01^{D}	1.43 ± 0.08	0.92 ± 0.09^{D}	1.48 ± 0.29^{D}
October	Triploid	10.89 ± 1.02^{E}	79.38 ± 6.57^{E}	76.27 ± 0.12	23.76 ± 0.15	19.45 ± 0.07	4.07 ± 0.08^{E}	1.26 ± 0.01	0.27 ± 0.04^{E}	1.89 ± 0.21^{E}
	Diploid	12.98 ± 2.84^{E}	74.48 ± 1.79^{E}	75.87 ± 0.37	24.13 ± 0.37	19.64 ± 0.03	2.37 ± 0.22^{E}	1.33 ± 0.08	1.03 ± 1.11^{E}	1.51 ± 0.23^{E}
November	Triploid	12.81 ± 1.47	80.06 ± 8.90^{F}	75.80 ± 0.09^{F}	24.20 ± 0.09^{F}	20.40 ± 0.46	4.08 ± 0.01^{F}	1.46 ± 0.01^{F}	0.73 ± 0.10^{F}	1.81 ± 0.34^{F}
	Diploid	13.21 ± 2.09	74.16 ± 1.47^{F}	78.19 ± 0.15^{F}	21.81 ± 0.15^{F}	19.11 ± 0.79	2.26 ± 0.10^{F}	1.67 ± 0.02^{F}	1.62 ± 2.43^{F}	1.51 ± 0.35^{F}

n: 3, the subscript uppercase letters (A, B, C, D, E, F) in the same column represent significant differences between triploid and diploid for the same month ($p<0.05$).

Table 4: Comparison of the fatty acid profiles (% total FAME) of triploid and diploid siblings of Black Sea trout (*Salmo trutta labrax*) fed on commercial pellets. The fatty acid profile of commercial pellets is also provided.

Fatty Acids	Commercial feeds	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER	
		Triploid	Diploid	Triploid	Diploid	Triploid	Diploid	Triploid	Diploid	Triploid	Diploid	Triploid	Diploid
C4:0	0.01 ± 0.00	0.02 ± 0.02	0.03 ± 0.00	0.06 ± 0.03	0.05 ± 0.01	0.04 ± 0.03	0.02 ± 0.02	0.08 ± 0.03	0.04 ± 0.00	0.07 ± 0.01	0.08 ± 0.01	0.13 ± 0.11	0.06 ± 0.05
C6:0	0.00 ± 0.00												
C8:0	0.01 ± 0.00												
C10:0	0.01 ± 0.00												
C11:0	0.00 ± 0.00												
C12:0	0.05 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.02 ± 0.00
C13:0	0.04 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00^{C}	0.02 ± 0.00^{C}	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
C14:0	4.14 ± 0.01	2.14 ± 0.16	2.17 ± 0.02	2.26 ± 0.14	2.01 ± 0.11	2.01 ± 0.10^{C}	1.64 ± 0.00^{C}	2.19 ± 0.00^{D}	1.40 ± 0.21^{D}	1.92 ± 0.07	1.90 ± 0.12	1.75 ± 0.07	1.57 ± 0.03
C15:0	0.00 ± 0.00	0.04 ± 0.04	0.07 ± 0.00	0.06 ± 0.01	0.04 ± 0.05	0.07 ± 0.00	0.06 ± 0.01	0.05 ± 0.03	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.00	0.01 ± 0.00^{F}	0.04 ± 0.00^{F}
C16:0	18.16 ± 0.02	15.89 ± 0.47	16.00 ± 0.09	16.55 ± 0.20^{B}	15.07 ± 0.39^{B}	16.08 ± 0.57	15.87 ± 0.31	13.98 ± 0.02	15.04 ± 0.93	14.35 ± 0.17	14.22 ± 0.17	13.09 ± 0.03	12.70 ± 0.26
C17:0	0.38 ± 0.01	0.25 ± 0.00	0.26 ± 0.00	0.27 ± 0.00	0.27 ± 0.02	0.27 ± 0.00	0.26 ± 0.01	0.24 ± 0.00^{D}	0.22 ± 0.00^{D}	0.21 ± 0.00	0.21 ± 0.01	0.19 ± 0.00	0.18 ± 0.01
C18:0	4.52 ± 0.02	4.37 ± 0.26	4.58 ± 0.14	4.57 ± 0.10	4.48 ± 0.08	4.75 ± 0.20	5.14 ± 0.15	4.34 ± 0.02	5.13 ± 0.68	4.27 ± 0.09	4.42 ± 0.04	4.07 ± 0.10	4.33 ± 0.17
C20:0	0.70 ± 0.00	0.34 ± 0.02	0.32 ± 0.01	0.26 ± 0.03	0.29 ± 0.02	0.23 ± 0.01	0.21 ± 0.01	0.25 ± 0.00	0.19 ± 0.05	0.01 ± 0.00^{E}	0.03 ± 0.00^{E}	0.02 ± 0.00	0.03 ± 0.00
C21:0	0.04 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.01	0.02 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00
C22:0	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00^{E}	0.01 ± 0.00^{E}	0.02 ± 0.00	0.01 ± 0.00
C23:0	0.02 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.01 ± 0.00^{D}	0.03 ± 0.00^{D}	0.02 ± 0.00	0.02 ± 0.00	0.01 ± 0.00^{F}	0.04 ± 0.00^{F}
C24:0	0.16 ± 0.00	0.10 ± 0.00	0.11 ± 0.03	0.09 ± 0.01	0.09 ± 0.01	0.08 ± 0.00	0.08 ± 0.00	0.09 ± 0.00^{D}	0.08 ± 0.00^{D}	0.07 ± 0.01	0.08 ± 0.00	0.07 ± 0.00	0.07 ± 0.01
∑SFA	28.26 ± 0.04	23.24 ± 0.61	23.62 ± 0.23	24.19 ± 0.15^{B}	22.40 ± 0.37^{B}	23.62 ± 0.24	23.38 ± 0.12	19.70 ± 0.19^{D}	22.64 ± 0.17^{D}	21.05 ± 0.35	21.08 ± 0.26	19.41 ± 0.16	19.10 ± 0.41
C14:1	0.65 ± 0.00	0.03 ± 0.00^{A}	0.02 ± 0.00^{A}	0.04 ± 0.00^{B}	0.01 ± 0.00^{B}	0.03 ± 0.00^{C}	0.02 ± 0.00^{C}	0.03 ± 0.00^{D}	0.02 ± 0.00^{D}	0.03 ± 0.00^{E}	0.02 ± 0.00^{E}	0.03 ± 0.00^{F}	0.02 ± 0.00^{F}
C15:1	0.01 ± 0.00	0.21 ± 0.00^{A}	0.37 ± 0.01^{A}	0.22 ± 0.01^{B}	0.34 ± 0.02^{B}	0.21 ± 0.01^{C}	0.30 ± 0.00^{C}	0.19 ± 0.01^{D}	0.14 ± 0.00^{D}	0.17 ± 0.01^{E}	0.29 ± 0.01^{E}	0.15 ± 0.00^{F}	0.14 ± 0.00^{F}
C16:1	3.65 ± 0.00	2.80 ± 0.13	2.54 ± 0.02	2.65 ± 0.14	2.44 ± 0.01	2.50 ± 0.08^{C}	1.88 ± 0.04^{C}	2.61 ± 0.02^{D}	1.71 ± 0.03^{D}	2.36 ± 0.10	2.32 ± 0.09	2.22 ± 0.07	1.91 ± 0.04
C17:1	0.01 ± 0.00	0.01 ± 0.01	0.04 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.04 ± 0.04	0.06 ± 0.00	0.01 ± 0.00	0.03 ± 0.03	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.04 ± 0.05
C18:1n9	20.50 ± 0.08	24.40 ± 0.39	23.41 ± 0.21	22.83 ± 0.64	23.46 ± 0.12	23.05 ± 0.28^{C}	20.86 ± 0.52^{C}	25.97 ± 0.67^{D}	22.38 ± 0.39^{D}	24.54 ± 0.96	24.78 ± 0.06	25.07 ± 0.04^{F}	23.03 ± 0.31^{F}
C20:1	0.07 ± 0.00	0.05 ± 0.00	0.04 ± 0.01	0.05 ± 0.00	0.05 ± 0.00	0.05 ± 0.00	0.04 ± 0.00	0.05 ± 0.00^{D}	0.04 ± 0.00^{D}	0.04 ± 0.00	0.05 ± 0.00	0.05 ± 0.00	0.05 ± 0.00
C22:1n9	0.63 ± 0.00	0.58 ± 0.09	0.51 ± 0.01	0.71 ± 0.08	0.76 ± 0.01	0.89 ± 0.06^{C}	1.11 ± 0.02^{C}	0.66 ± 0.01^{D}	1.26 ± 0.03^{D}	0.75 ± 0.03	0.80 ± 0.05	0.75 ± 0.04	0.88 ± 0.05
C24:1	0.03 ± 0.00	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.00	0.04 ± 0.00	0.04 ± 0.00^{C}	0.03 ± 0.00^{C}	0.04 ± 0.00	0.04 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00
∑MUFA	25.55 ± 0.08	28.42 ± 0.45	26.97 ± 0.20	26.89 ± 0.72	27.11 ± 0.10	27.11 ± 0.28^{C}	24.33 ± 0.51^{C}	29.86 ± 0.72^{D}	25.61 ± 0.41^{D}	28.20 ± 0.15	28.31 ± 0.00	28.55 ± 0.19	27.10 ± 0.383
C18:2n6	15.89 ± 0.06	21.17 ± 0.97	21.01 ± 0.61	18.03 ± 0.87	20.51 ± 0.44	17.05 ± 0.62	17.42 ± 0.64	19.34 ± 0.27	16.70 ± 1.93	17.75 ± 0.67	17.61 ± 0.06	19.05 ± 0.51	18.23 ± 0.12
C18:3n3	2.28 ± 0.01	2.03 ± 0.12	1.93 ± 0.08	1.84 ± 0.09	1.86 ± 0.06	1.67 ± 0.06	1.55 ± 0.01	2.09 ± 0.01^{D}	1.72 ± 0.09^{D}	3.16 ± 0.21^{E}	3.98 ± 0.12^{E}	3.44 ± 0.30^{F}	4.24 ± 0.11^{F}
C18:3n6	0.66 ± 0.00	1.28 ± 0.04^{A}	1.13 ± 0.01^{A}	1.19 ± 0.03	1.15 ± 0.00	1.46 ± 0.09^{C}	1.14 ± 0.01^{C}	1.84 ± 0.01	1.56 ± 0.16	1.55 ± 0.06	1.45 ± 0.02	1.79 ± 0.16	1.57 ± 0.08
C20:2	0.01 ± 0.00	0.13 ± 0.02	0.17 ± 0.01	0.16 ± 0.01	0.16 ± 0.01	0.17 ± 0.00	0.10 ± 0.00	0.17 ± 0.01	0.15 ± 0.00	0.15 ± 0.00	0.16 ± 0.01	0.14 ± 0.00	0.14 ± 0.00
C20:3n3	0.16 ± 0.00	0.20 ± 0.00	0.21 ± 0.00	0.21 ± 0.00^{B}	0.11 ± 0.01^{B}	0.21 ± 0.00^{C}	0.17 ± 0.00^{C}	0.25 ± 0.00^{D}	0.21 ± 0.01^{D}	0.28 ± 0.01	0.29 ± 0.00	0.30 ± 0.00	0.32 ± 0.01
C20:3n6	0.11 ± 0.01	0.40 ± 0.02^{A}	0.17 ± 0.06^{A}	0.34 ± 0.00	0.41 ± 0.02	0.42 ± 0.00	0.40 ± 0.01	0.64 ± 0.07	0.57 ± 0.01	0.66 ± 0.03	0.65 ± 0.03	0.71 ± 0.04	0.68 ± 0.03
C20:5n3	6.08 ± 0.05	1.70 ± 0.07	1.73 ± 0.01	2.11 ± 0.08	2.17 ± 0.11	2.37 ± 0.08^{C}	2.78 ± 0.04^{C}	1.94 ± 0.04^{D}	2.83 ± 0.06^{D}	2.16 ± 0.15	2.22 ± 0.05	2.19 ± 0.16	2.36 ± 0.06
C22:2	0.02 ± 0.00	0.02 ± 0.00^{A}	0.01 ± 0.00^{A}	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00^{C}	0.01 ± 0.00^{C}	0.02 ± 0.00^{D}	0.01 ± 0.00^{D}	0.01 ± 0.00^{E}	0.02 ± 0.00^{E}	0.01 ± 0.00	0.02 ± 0.00
C22:6n3	9.53 ± 0.17	11.98 ± 0.82	12.71 ± 0.56	14.65 ± 0.86	14.30 ± 0.23	15.54 ± 0.89	18.48 ± 0.08	11.44 ± 0.21^{D}	18.16 ± 0.68^{D}	14.29 ± 0.10	12.88 ± 0.57	13.21 ± 0.55	14.25 ± 0.54
∑PUFA	34.74 ± 0.31	38.82 ± 0.79	39.06 ± 0.17	38.46 ± 0.04	40.75 ± 0.86	38.80 ± 0.39^{C}	42.05 ± 0.60^{C}	37.62 ± 0.58	41.91 ± 0.41	39.89 ± 0.26	39.27 ± 0.84	40.66 ± 0.80	41.81 ± 0.50
EPA+DHA	15.62 ± 0.23	13.68 ± 0.89	14.44 ± 0.57	16.77 ± 0.94	16.47 ± 0.34	17.91 ± 0.98^{C}	21.26 ± 0.04^{C}	13.38 ± 0.25^{D}	20.99 ± 0.54^{D}	16.44 ± 0.25	15.10 ± 0.62	15.29 ± 0.12	16.61 ± 0.60
∑n3	18.06 ± 0.24	15.92 ± 1.77	16.58 ± 0.50	18.82 ± 0.85	18.51 ± 0.40	19.79 ± 0.92^{C}	22.98 ± 0.06^{C}	15.72 ± 0.27^{D}	22.92 ± 0.46^{D}	19.89 ± 1.03	19.38 ± 0.74	19.04 ± 1.42	21.17 ± 0.51
∑n6	16.65 ± 0.07	22.85 ± 0.95	22.30 ± 0.67	19.57 ± 0.90	22.06 ± 0.46	18.93 ± 0.53	18.97 ± 0.66	21.82 ± 0.32	18.82 ± 0.25	20.00 ± 0.77	19.72 ± 0.10	21.56 ± 0.62	20.47 ± 0.01
∑n3/∑n6	1.08 ± 0.01	0.70 ± 0.11	0.74 ± 0.04	0.96 ± 0.09	0.84 ± 0.00	1.05 ± 0.08	1.21 ± 0.05	0.72 ± 0.00	1.24 ± 0.32	1.00 ± 0.09	0.98 ± 0.03	0.88 ± 0.09	1.03 ± 0.02
∑n6/∑n3	0.92 ± 0.01	1.45 ± 0.22	1.35 ± 0.08	1.04 ± 0.09	1.19 ± 0.00	0.96 ± 0.07	0.83 ± 0.03	1.39 ± 0.00^{D}	0.84 ± 0.02^{D}	1.01 ± 0.09	1.02 ± 0.03	1.14 ± 0.12	0.97 ± 0.02
Other	11.45 ± 0.43	9.53 ± 0.95	10.35 ± 0.13	10.46 ± 0.61	9.74 ± 0.34	10.46 ± 0.75	10.24 ± 1.00	12.83 ± 2.82	9.84 ± 2.38	10.85 ± 1.31	11.35 ± 0.59	11.38±0.45	12.00±0.29

Mean ± SD, n: 3, the subscript uppercase letters (A, B, C, D, E, F) in the same row represent significant differences between triploid and diploid for the same month ($p<0.05$)

DISCUSSION

In this study, the growth rate of sexually immature (fry and fingerling) triploid and diploid Black Sea trout were identical. The identical growth rate of immature triploid and diploid fish was also reported by Gervai et al., (1980) for carp (*Cyprinus carpio*), Oliva-Teles and Kaushik (1990) and Teuscher et al., (2003) for rainbow trout (*Oncorhynchus mykiss*), Fast et al., (1995) for Asian Catfish (*Clarias macrocephalus*), and Galbreath and Thorgaard (1997) for Atlantic salmon (*Salmo salar*). Such results suggest no metabolic advantage resulting from triploidy before sexual maturation (Koedprang and Na-Nakorn, 2000). The growth rate of juvenile triploid Black Sea trout was significantly higher than diploid siblings, which is in line with the findings of Purdom (1976) for Flatfish species, Thorgaard and Gall (1979) adult rainbow trout, and Wolters et al. (1982) for channel catfish (*Ictalurus punctatus*). Generally, triploids are expected to grow faster compared to their diploid siblings as they have more genes (33%), larger nuclei and cells size, and usually no energy allocation to developing gonads (Manor et al., 2012; Maxime, 2008). Despite these facts, several studies have reported lower growth rates of triploids than diploids (Cassani and Caton, 1986; Galbreath et al., 1994; McGeachy et al., 1995; Sacobie et al., 2015) or no significant differences in their growth rates (Kim et al., 1994; Hussain et al., 1995; McGeachy et al., 1996). However, this may not necessarily mean that triploids grow less efficiently than diploid as these studies raised both ploidy groups communally. Since, triploids are generally less aggressive and outcompeted by their diploid counterparts for food (cited in Maxime, 2008) and these behavioural differences may lead to the lower growth rate of triploids than diploids siblings (Cassani and Caton, 1986; Lincoln and Bye, 1987). According to Sacobie et al., (2015) triploids may divert more of their digestible energy to cope with stress (Benfey, 1999; Fraser et al., 2012; Maxime, 2008) negatively affecting their overall growth.

A significant effect of triploidy on the fat contents of Black Sea trout was observed throughout the study, which is consistent with previous studies (Manor et al., 2012; Poontawee et al., 2007; Sacobie et al., 2015; Werner et al., 2008). Triploid Black Sea trout had significantly higher fat contents than diploid siblings, which is also in line with the results of previous studies (Aussanasuwannakul et al., 2011; Poontawee et al., 2007; Taylor et al., 2013).

Higher carcass ratio of triploids may be due to more fat deposits (Koedprang and Na-Nakorn, 2000). In this study, the percent carcass ratio of triploid and diploid Black Sea trout was showed significant differences in the last four months of this study (higher than diploid by ~5.9%). These findings are consistent with those reported by Poontawee et al. (2007) in rainbow trout (higher than diploid by 14%). In contrast to these results, no significant differences were reported for carcass percentages of diploid and triploid Thai silver barb, *Puntius gonionotus* (Koedprang and Na-Nakorn, 2000).

This study recorded no consistent effects of triploidy on moisture contents, dry matter, total protein and ash contents, and they appeared to be similar between triploid and diploid Black Sea trout. These findings are consistent with the results of previous studies reporting no effects of triploidy on the proximate composition of rainbow trout (Muller-Belecke et al., 2006) and Masu Salmon (*O. masou*) (Wang et al., 2015). Furthermore, consistent with our findings, several studies have reported smaller values of GSI for triploids in comparison to the diploids siblings (Henken et al., 1987; Johnson et al., 1986; Kızak et al., 2013; Koedprang and Na-Nakorn, 2000; Lincoln and Scott, 1983; Lincoln and Scott, 1984; Segato et al., 2006; Werner et al., 2008).

CONCLUSIONS

The results of this study evinced no metabolic advantage resulting from triploidy before sexual maturation of fish. However, a better growth rate was observed in maturing triploid Black Sea trout than their diploid counterparts. Their higher weight gain and carcass ratio might be due to higher fat content, and smaller GSI values. Except the fat contents, the proximate composition and fatty acid profiles were generally found similar between triploid and diploid revealing no effects of triploidy on the proximate composition. Hence, the results of this study suggest considering triploid Black Sea trout by fish farmer for their better growth rate than diploid with same muscle qualities and nutritional values provided by their diploid counterparts.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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