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Comparative Fatty Acid Compositions of Tissues of Rainbow Trout (*Oncorhynchus mykiss*) with Different Ploidy and Sex

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ABSTRACT

The purpose of this study was to evaluate the fatty acid contents in various tissues (fillet, liver, gonad) of different ploidy (triploid and diploid) and sex (female and male) rainbow trout (*Oncorhynchus mykiss*) in the breeding season. In the study, diploid and triploid rainbow trouts belonging to the same age group (3+) were used. Fish were fed with commercial feed containing 45% crude protein and 20% crude fat until satiation. At the end of the 75-day study, biometric measurements of the fish were made and the tissues were stored in a deep freezer until biochemical and fatty acid analysis. The first finding of this study identified that ploidy (triploid and diploid) affects the biochemical and fatty acid composition of rainbow trout. The second major finding was that the polyunsaturated fatty acid values were higher and the saturated fatty acid values were lower in all tissues (especially female gonads) than other fatty acids. The results also indicate that the comparative among the biochemical and fatty acid composition of the fillet, liver, and gonad of rainbow trout is further illuminated by these data.

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Introduction

Fish and fish oils include omega-3 fatty acids, containging eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Holub and Holub, 2004), which originate in the food chain from phytoplankton and seaweed (Visentainer et al., 2007). Recent studies have demonstrated that the omega-3 fatty acids EPA and DHA, which are plentiful in fish tissues, have beneficial impacts on the creation of bones and metabolism as well as reducing the risk of cardiovascular disease (Su et al., 2003; Watkins et al., 2003; Lombardo et al., 2007). The total fat and fatty acid compositions of all fish species vary depending on the season, the area where they were caught, their size, diet, sex, and the stage of their reproductive cycle (Shirai et al., 2001, Shirai et al., 2002; Luzia et al., 2003; Görgün and Akpınar, 2007). While fatty fishes (such as *Salmo salar*, *Oncorhynchus mykiss*, and *Clupea harengus*) store fat primarily in muscle tissue, lean fishes store fat in body cavities and perivisceral organs (e.g. liver). The liver is a vital organ for lipid metabolism, and the majority of fish utilized for the human diet is muscle. Therefore, the livers of lean fish tend to be fatter than those of fatty fish (Uysal et al., 2006). For example, the muscles of fish used in fish oil production contain less fat than their livers (Jacobsen et al., 2022). Sexual maturation is a primary physiological process that results in a transition from somatic to gonadal development. (Taranger et al., 2010). Gonadal growth occurs at the expending of stored energy and nutrients, including fats, in many farmed fish species, including salmonids (Manor et al., 2015). Sexual maturation period, female rainbow trout grow ovaries that account for more than 20% of total body weight (Taranger et al., 2010). Because maturing females cannot digest enough nutrients from their diet to maintain gonadal growth, they must mobilize energy reserves to meet the increasing energy demand (Memiş and Gun, 2004; Salem et al., 2006, Salem et al., 2007; Aussanasuwannakul et al., 2011, Ribeiro et al., 2011; Aussanasuwannakul et al., 2012; Manor et al., 2012). Throughout maturation, lipids are mobilized from visceral adipose tissue and muscle reserves (Aussanasuwannakul et al., 2011; Manor et al., 2012). Nonetheless, the quantity and makeup of nutritional reserves, diet composition, and ratio levels are likely to influence sexual maturation and affect body composition (Manor et al., 2015). Consequently, nutrients for germinal tissue development must be obtained from other tissues such as muscle and liver. According to Uysal et al. (2006)

females primarily use saturated fatty acids to satisfy the energy requirements of gonad development, whereas males mostly use monounsaturated fatty acids. The aim of this study was to compare the fatty acid composition of muscle, liver, and gonads of rainbow trout of different sexes and ploidy.

Material and Methods

The research was carried out at Research and Application Center in Sinop University Fisheries Faculty. In the research, 9 cylindrical-shaped fiberglass tanks, each with a volume of 2000 L, were used for 75 days. The fish were divided into three groups according to sex and ploidy: diploid female (DF), diploid male (DM) and triploid female (TM). Natural flow water systems and aeration were used for each tank. Triploid and diploid rainbow trout (at 3 years old) were brought from a trading company (Kuzey Aquaculture Inc.) in Samsun, Turkey. According to the random sampling method, 9 fish with average weights >1kg (Group DF 1302.89±64.93g; Group DM 1453.55±194.03g and Group TF 1632.40±217.90g) were added to each tank from the stock tank. The Black Sea Feed (Sinop-Turkey), a commercial diet manufacturer, made the fish diet using a closed diet formula for large rainbow trout. In pursuant to the manufacturer's diet label, the biochemical composition of the diet and fatty acid composition results of diet are shown in Table 1.

Water parameters were determined daily with a field-type (YSI 556 MPS model) multiparameter measurement instrument and the water temperature was an average of 13.87±0.14ºC and the O_2 values were an average of 6.87±0.12mg/L. Fish were killed with a high dose of anesthesia (MS-222, 25–50 mg/L, Ortuno et al., 2002). The sampled fish were brought to the Faculty of Fisheries and Aquaculture. In the laboratory, fish were cut into boneless fillets by separating their internal organs and skins, they were kept in a deep freezer (WiseCryo/WUFD50080°C) until analysis. The biometric data were calculated according to Jobling (2010).The biochemical analyses of the gonad, liver and fillets samples was evaluated using AOAC-approved procedures (1990). Fatty acid analyses were performed in the Marmara Research Center of the Scientific and Technological Research Council of Turkey (TUBITAK MAM) using IUPAC gas chromatography (Firestone and Horwitz, 1979). Total fatty acids and fatty acid quality assessments were calculated according to Ulbricht and Southgate, (1991) and Santos-Silva et al., (2002). Where; AI= Atherogenicity Index; TI= Thrombogenicity Index; H/H= Hypocholesteroemic/ Hypercholesterolemic ratio

$$\mathrm{AI} = \frac{[(\mathrm{C12{:}0} + (4 \times \mathrm{C14{:}0}) + \mathrm{C16{:}0})]}{(\mathrm{MUFA} + \sum n-3 + \sum n-6)}$$

$$\mathrm{TI} = ((\mathrm{C14{:}0} + \mathrm{C16{:}0} + \mathrm{C18{:}0}))/[(0.5 \times \mathrm{MUFA}) + (0.5 \times \sum \mathrm{n}-6) + (3 \times \sum \mathrm{n}-3) + (\sum \mathrm{n}-3/(\sum \mathrm{n})-6)]$$

$$H/H = ((\mathrm{C18{:}1n}-9 + \mathrm{C18{:}2n}-6 + \mathrm{C18{:}3n}-3 + \mathrm{C20{:}4n}-6 + \mathrm{C20{:}5n}-3 + \mathrm{C22{:}6n}-3))/((\mathrm{C14{:}0} + \mathrm{C16{:}0}))$$

The data were presented as average values with standard error (SE). For statistical analysis, the IBM SPSS 21 statistics package program was employed. Oneway ANOVA was used to assess the importance of the data differences, and Tukey's multiple comparisons process was used to assess its accuracy.

Table 1. The biochemical and fatty acid compositions of the diets

Biochemical composition (%)*	
Crude Protein	45
Crude Fat	20
Crude Ash	10
Dry Matter	90
Fatty acid composition (%)	
C12:0	0.09±0.01
C13:0	0.01±0.01
C14:0	1.31±0.01
C15:0	0.15±0.01
C16:0	14.04±0.02
C17:0	0.20±0.01
C18:0	4.19±0.02
C20:0	0.43±0.01
C22:0	0.22±0.01
C23:0	0.01±0.01
C24:0	0.08±0.01
C14:1	0.03±0.01
C16:1	1.91±0.01
C18:1n-9c	24.17±0.01
C20:1n-9c	0.05±0.01
C24:1	0.07±0.01
C18:2n-6c	39.30±0.06
C18:3n-3	4.81±0.01
C18:3n-6	0.09±0.01
C20:2	0.18±0.01
C20:3n-3	0.06±0.01
C20:3n-6	0.05±0.01
C20:4n-6	0.18±0.01
C20:5n-3	1.21±0.02
C22:5n-3	0.18±0.01
C22:6n-3	1.55±0.01
ΣSFA	20.70±0.04
ΣMUFA	26.42±0.23
ΣPUFA	47.59±0.02

*According to the manufacturer's label, the biochemical composition of the diet

Results

The weight and length and biometric index of diploid female (DF), diploid male (DM) and triploid female (TF) are given Table 2.

Viscerosomatic index (VSI) values were in the highest TF group and lowest in the DM group, and the difference between the VSI values of female and male fish was statistically significant ($p<0.05$). Hepatosomatic index (HSI) values were like VSI values, in the highest TF group, and in the lowest DM group, the difference between the HSI values of all groups was significant ($p<0.05$).

The biochemical compositions of fish fillets and gonads are shown in Table 3. In the fillets the highest crude protein (CP) value was in the TF group, the highest crude fat (CF) value was in the DM group, and the statistical difference between the groups was significant ($p<0.05$).

Table 2. The length-weights and biometric indexes of fish

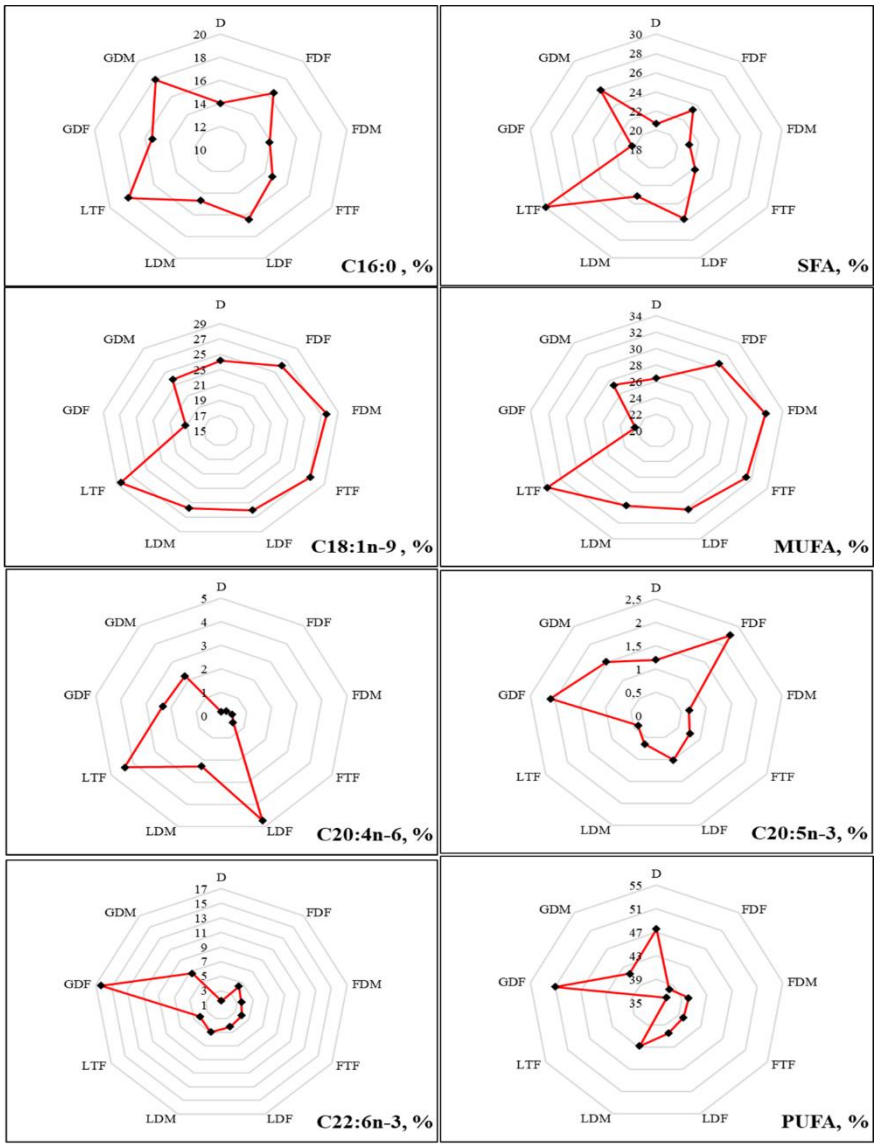
Parameters	DF	DM	TF
Weight (g)	1302.89±64.93	1453.55±194.03	1632.40±217.90
Lenght (cm)	43.24±0.66	44.58±1.34	46.40±1.39
VSI (%)	14.07±0.81^{b}	12.19±0.82^{a}	15.09±1.02^{b}
HSI (%)	1.26±0.07^{b}	1.05±0.04^{a}	1.42±0.06^{c}
GSI (%)	2.49±0.15^{b}	1.43±0.32^{a}	-

Each value means mean±standard error. Values expressed with different exponential letters on the same line are statistically different from each other ($p<0.05$); VSI= viscerosomatic index, HSI = hepatosomatic index, GSI= gonadosomatic index

Table 3. The biochemical composition of fish fillets and gonads

Biochemical composition	Fillets			Gonad	
	DF	DM	TF	DF	DM
CP (%)	21.85±0.45^{b}	20.42±0.12^{a}	22.41±0.18^{c}	21.91±0.14^{y}	20.20±0.11^{x}
CF (%)	7.14±0.24^{a}	12.19±0.03^{c}	9.10±0.08^{b}	11.83±0.15^{y}	5.86±0.66^{x}
CA (%)	1.47±0.08^{a}	1.46±0.04^{a}	1.57±0.14^{b}	2.25±0.17^{x}	2.27±0.01^{x}
DM (%)	30.05±0.64^{a}	34.23±0.28^{b}	33.21±0.28^{b}	37.87±1.21^{y}	28.89±0.47^{x}

CP= crude protein, CF= crude fat, CA=crude ash, DM= dry matter, Each value means mean±standard error. Values expressed with different exponential letters on the same line are statistically different from each other ($p<0.05$); a, b: The differences between the means with different letters on the same line within the biochemical composition of fillets are statistically significant ($p<0.05$); x, y: The differences between the means with different letters on the same line between the biochemical composition of gonads are statistically significant ($p<0.05$).



D:Diet; FDF: diploid female fillets; FDM: diploid male fillets; FTF: triploid female fillets; LDF: diploid female liver; LDM: diploid male liver; LTF: triploid female liver; GDF: diploid female gonad ; GDM: diploid male gonad

Figure 1. The selected fatty acids in feed and different tissues of rainbow trout

Table 4. Fatty acid composition of DF, DM and TF fillets (%)

Fatty acid	DF	DM	TF	Fatty acid	DF	DM	TF
C12:0	0.09±0.03^{b}	0.05±0.01^{a}	0.04±0.01^{a}	C18:3n-6	0.31±0.01^{a}	0.55±0.01^{c}	0.47±0.01^{b}
C13:0	0.01±0.01^{a}	0.01±0.01^{a}	0.01±0.01^{a}	C20:2	0.83±0.01^{a}	1.56±0.01^{c}	1.48±0.01^{b}
C14:0	2.10±0.01^{b}	1.55±0.01^{a}	1.54±0.01^{a}	C20:3n-3	0.12±0.01^{a}	0.16±0.01^{b}	0.12±0.01^{a}
C15:0	0.28±0.01^{b}	0.18±0.01^{a}	0.19±0.01^{a}	C20:3n-6	0.01±0.01^{a}	0.88±0.02^{c}	0.67±0.01^{b}
C16:0	16.43±0.01^{c}	13.89±0.01^{a}	14.68±0.03^{b}	C20:4n-6	0.29±0.01^{a}	0.43±0.01^{b}	0.53±0.01^{c}
C17:0	0.29±0.01^{b}	0.22±0.01^{a}	0.23±0.01^{a}	C20:5n-3	2.26±0.01^{c}	0.66±0.01^{a}	0.76±0.01^{b}
C18:0	3.55±0.02^{a}	4.51±0.01^{b}	4.88±0.01^{b}	C22:2	0.04±0.01^{a}	0.11±0.01^{b}	0.09±0.01^{b}
C20:0	0.38±0.02^{b}	0.33±0.01^{a}	0.31±0.01^{a}	C22:5n-3	0.41±0.01^{b}	0.35±0.01^{a}	0.41±0.01^{b}
C22:0	0.11±0.01^{a}	0.13±0.01^{a}	0.12±0.01^{a}	C22:6n-3	4.39±0.01^{a}	3.54±0.01^{a}	3.92±0.04^{b}
C23:0	0.11±0.01^{a}	0.18±0.01^{b}	0.16±0.01^{b}	ΣPUFA	38.09±0.02^{a}	40.07±0.02^{c}	39.89±0.02^{b}
C24:0	0.04±0.01^{a}	0.12±0.01^{b}	0.05±0.01^{a}	ΣOmega-3	10.47±0.01^{c}	6.66±0.06^{a}	8.09±0.04^{b}
ΣSFA	23.37±0.04^{c}	21.16±0.01^{a}	22.21±0.02^{b}	ΣOmega-6	26.75±0.03^{a}	30.85±0.01^{b}	30.24±0.01^{b}
C14:1	0.04±0.01^{b}	0.02±0.01^{a}	0.02±0.01^{a}	ΣOmega-9	27.21±0.02^{a}	29.00±0.01^{c}	28.37±0.01^{b}
C16:1	3.30±0.01^{c}	2.98±0.01^{b}	2.85±0.01^{a}	n3/n6	0.39±0.01^{b}	0.24±0.01^{a}	0.27±0.01^{a}
C18:1n-9c	26.09±0.02^{a}	27.61±0.02^{b}	27.11±0.01^{b}	n6/n3	2.55±0.02^{a}	4.08±0.02^{c}	3.74±0.02^{b}
C20:1n-9c	1.12±0.01^{a}	1.39±0.01^{c}	1.26±0.01^{b}	EPA/DHA	0.51±0.01^{b}	0.19±0.01^{a}	0.19±0.01^{a}
C24:1	0.11±0.01^{a}	0.12±0.01^{a}	0.10±0.01^{a}	EPA+DHA	6.65±0.01^{b}	4.20±0.01^{a}	4.46±0.04^{a}
ΣMUFA	30.66±0.03^{a}	32.12±0.02^{c}	31.33±0.01^{b}	AI	0.37±0.01^{b}	0.29±0.01^{a}	0.30±0.01^{a}
C18:2n-6t	26.06±0.02^{a}	29.00±0.01^{b}	28.58±0.02^{b}	TI	0.36±0.01^{a}	0.37±0.01^{a}	0.38±0.01^{a}
C18:3n-3	3.29±0.01^{b}	2.85±0.03^{a}	2.88±0.01^{a}	PUFA/SFA	1.63±0.01^{a}	1.89±0.01^{b}	1.80±0.01^{b}
				H/H	3.37±0.01^{a}	4.15±0.01^{c}	3.93±0.01^{b}

The each value means mean±standard error. Values expressed with different exponential letters on the same line are statistically different from each other ($p<0.05$); a, b, c: The differences between the means with different letters on the same line within the group are statistically significant ($p<0.05$).

Table 5. Fatty acid composition of DF, DM and TF livers (%)

Fatty acid	DF	DM	TF	Fatty acid	DF	DM	TF
C12:0	0.21±0.02^{b}	0.12±0.01^{a}	0.36±0.02^{c}	C18:3n-6	0.50±0.01^{b}	0.42±0.01^{a}	ND
C14:0	1.39±0.01^{b}	1.42±0.01^{c}	1.20±0.01^{a}	C20:2	2.69±0.01^{b}	1.85±0.01^{a}	2.73±0.03^{b}
C16:0	16.40±0.32^{b}	14.66±0.02^{a}	18.34±0.23^{c}	C20:3n-3	ND	0.10±0.01^{a}	0.45±0.03^{b}
C17:0	ND	0.21±0.01	ND	C20:3n-6	1.71±0.04^{b}	1.22±0.01^{a}	1.67±0.03
C18:0	6.75±0.08^{b}	6.13±0.07^{a}	9.15±0.01^{c}	C20:4n-6	4.72±0.06^{b}	2.28±0.01^{a}	4.37±0.01^{b}
C20:0	ND	0.23±0.01	ND	C20:5n-3	1.01±0.09^{c}	0.65±0.01^{b}	0.41±0.05^{a}
C22:0	ND	0.15±0.01	ND	C22:5n-3	ND	0.32±0.02	ND
C23:0	0.94±0.01^{b}	0.08±0.01^{a}	0.92±0.02^{b}	C22:6n-3	4.18±0.12^{a}	4.96±0.01^{b}	4.15±0.01^{a}
ΣSFA	25.69±0.26^{b}	23.15±0.02^{a}	29.96±0.26^{c}	ΣPUFA	40.46±0.26^{b}	42.78±0.03^{c}	33.16±0.25^{a}
C16:1	2.93±0.14^{b}	2.30±0.02^{a}	2.90±0.04^{b}	ΣOmega-3	6.81±0.24^{b}	8.34±0.03^{c}	6.26±0.01^{a}
C18:1n-9c	26.00±0.04^{a}	25.76±0.03^{a}	28.55±0.08^{b}	ΣOmega-6	30.97±0.03^{b}	32.59±0.01^{c}	24.18±0.21^{a}
C20:1n-9c	1.28±0.08^{a}	1.20±0.01^{a}	1.96±0.05^{b}	ΣOmega-9	27.27±0.11^{a}	26.95±0.03^{a}	30.51±0.14^{b}
C24:1	ND	0.44±0.01^{a}	0.40±0.08^{a}	n3/n6	0.22±0.01^{a}	0.26±0.01^{b}	0.26±0.01^{b}
ΣMUFA	30.20±0.02^{b}	29.68±0.05^{a}	33.80±0.01^{c}	n6/n3	4.56±0.15^{a}	3.91±0.01^{b}	3.87±0.03^{b}
C18:2n-6t	24.04±0.08^{b}	28.68±0.03^{c}	18.14±0.18^{a}	EPA/DHA	0.24±0.01^{b}	0.13±0.01^{a}	0.10±0.02^{a}
C18:3n-3	1.63±0.03^{b}	2.32±0.02^{c}	1.26±0.09^{s}	EPA+DHA	5.18±0.20^{b}	5.60±0.02^{c}	4.56±0.07^{a}

ND:non-detected; The each value means mean±standard error. Values expressed with different exponential letters on the same line are statistically different from each other ($p<0.05$); a, b, c: The differences between the means with different letters on the same line within the group are statistically significant ($p<0.05$).

Table 6. Fatty acid composition of DF, DM and TF gonads(%)

Fatty acid	DF	DM	Fatty acid	DF	DM
C12:0	0.02±0.01^{a}	0.09±0.01^{b}	C18:3n-3	2.34±0.01^{b}	2.13±0.01^{a}
C14:0	0.85±0.01^{a}	1.52±0.01^{b}	C18:3n-6	0.59±0.01^{b}	0.38±0.01^{a}
C15:0	0.19±0.01^{a}	0.21±0.01^{a}	C20:2	2.14±0.01^{b}	1.63±0.01^{a}
C16:0	15.44±0.01^{a}	17.92±0.02^{b}	C20:3n-3	0.05±0.01^{a}	0.08±0.01^{b}
C17:0	0.19±0.01^{a}	0.23±0.01^{b}	C20:3n-6	1.84±0.01^{b}	1.08±0.01^{a}
C18:0	3.36±0.02^{a}	5.57±0.01^{b}	C20:4n-6	2.35±0.05^{b}	2.22±0.01^{a}
C20:0	0.09±0.02^{a}	0.19±0.01^{b}	C20:5n-3	2.10±0.01^{b}	1.52±0.01^{a}
C22:0	0.01±0.01^{a}	0.12±0.01^{b}	C22:2	0.11±0.01	ND
C23:0	0.19±0.01^{b}	0.12±0.05^{a}	C22:5n-3	0.74±0.01^{b}	0.36±0.01^{a}
ΣSFA	20.32±0.01^{a}	26.13±0.09^{b}	C22:6n-3	16.34±0.05^{b}	6.71±0.04^{a}
C14:1	0.01±0.01	ND	ΣPUFA	51.07±0.01^{b}	41.49±0.11^{a}
C16:1	2.47±0.01^{b}	2.20±0.01^{a}	ΣOmega-3	21.56±0.07^{b}	10.79±0.04^{a}
C18:1n-9c	19.19±0.01^{a}	23.77±0.01^{b}	ΣOmega-6	27.26±0.07^{a}	29.08±0.06^{b}
C20:1n-9c	0.70±0.01^{a}	1.04±0.01^{b}	ΣOmega-9	19.89±0.01^{a}	24.81±0.01^{b}
C24:1	0.01±0.01^{a}	0.27±0.01^{b}	n3/n6	0.79±0.01^{b}	0.37±0.01^{a}
ΣMUFA	22.38±0.01^{a}	27.27±0.01^{b}	n6/n3	1.26±0.01^{a}	2.70±0.01^{b}
C18:2n-6t	22.49±0.02^{a}	25.41±0.05^{b}	EPA/DHA	0.13±0.01^{a}	0.23±0.01^{b}
			EPA+DHA	18.43±0.06^{b}	8.23±0.04^{a}

ND:non-detected; The each value means mean±standard error. Values expressed with different exponential letters on the same line are statistically different from each other ($p<0.05$); a, b, c: The differences between the means with different letters on the same line within the group are statistically significant ($p<0.05$).

In the gonads, the highest dry matter (DM), CP, and CF values were determined in the DF group ($p<0.05$). The statistical difference between the crude ash (CA) values of the gonads was not significant ($p>0.05$).

The fatty acid compositions in the fillet, liver, and gonads of fish are given in Tables 4, 5 and 6, Figure 1 respectively. In the study, C12:0, C14:0, C15:0, C16:0, C17:0 and C20:0 values were high in DF, C23:0 and C24:0 values were high in DM, C18:0 value was higher in TF fillets. The highest SFA value was in the DF group and the difference among the SFA values determined in the fillets was significant ($p<0.05$). The ΣMUFA order of the fillets was as DM>TF>DF and the statistical difference among the ΣMUFA values in the fillets was significant ($p<0.05$).

The C18:3n-3, C20:5n-3, and C22:6n-3 were highest in DF fillets ($p<0.05$). While the C18:2n-6t, C18:3n-6, C20:2, C20:3n-3, and C20:3n-6 fatty acids were highest in DM fillets, the C20:4n-6 was highest in TF fillets. The ΣPUFA order of the fillets was as DM>TF>DF and the statistical difference among the ΣPUFA values in the fillets was significant ($p<0.05$).

In the study, C17:0, C20:0, C22:0, and C22:5n-3 fatty acids were not detected in the livers of both diploid and triploid female fish. In the fatty acid analysis performed in livers, ΣSFA and ΣMUFA values were higher in the TF group, and ΣPUFA values were higher in the DM group ($p<0.05$).

The EPA rankings of livers were as DF>DM>TF and the statistical difference among groups was significant ($p<0.05$). The DHA value of liver was found to be higher in both the DM group and statistically significant ($p<0.05$).

The saturated and monounsaturated fatty acids in the gonads of diploids were higher in male gonads (except C23:00 and C16:1). The polyunsaturated fatty acids were higher in diploid female gonads (except C20:3n-6). The C14:1 and C22:2 fatty acids could not be detected in diploid male gonads.

The ΣOmega-3 fatty acids of the gonads were higher in the DF group ($p<0.05$), and ΣOmega-6 and ΣOmega-9 fatty acids of the gonads were higher in the DM group ($p<0.05$).

When fatty acids in all tissues were evaluated, saturated fatty acids and monounsaturated fatty acids were determined more in fillets, liver, and gonads (Figure 1). The PUFAs such as EPA and DHA generally came to the fore in the gonads.

Discussion

There are many studies comparing growth parameters, meat yields, and biochemical compositions of diploid and triploid fish (Manor et al., 2012; Kızak et al., 2013; Weber et al., 2014; Wang et al., 2015; Karbalaei et al., 2017; Liu et al., 2018; Ignatz et al., 2020; Meiler and Kumar, 2021). The purpose of this study was to evaluate the biochemical and fatty acid compositions of differend sex and ploidy of rainbow trout's different tissues. There have been many studies comparing the biochemical composition of triploid and diploid fish, but the outcomes are different. The crude protein and ash content of TF fillets, as well as the crude fat and dry matter content of DM, were high in the current research. When the biochemical compositions of females were compared, all biochemical parameters of TF were higher than DF. Manor et al. (2014) reported that crude fat in triploid rainbow trout and crude protein in diploid rainbow trout were high. Diploid and triploid fish's biochemical characteristics showed no modification, according to Wang et al. (2015). According to Poontawee et al. (2007), ploidy had no influence on fish biochemical composition, particularly crude protein ratio. dos Santos et al. (1993) drew attention to the importance of the relationship between the biochemical composition of fish and their diet profiles and even suggested that separate dietary rations could be prepared for female and male broodstocks. Shearer (1994) and Ignatz et al. (2020) reported in their study that there is a relationship between the biochemical composition of fish, water temperature, and the protein/fat ratio of the diet. Given these findings, the fact that the TF group in our study had more crude fat and crude protein than the DF group despite feding the same diet and being raised in the same environment demonstrates the impact of ploidy. Manor et al. (2015) suggest that male and female rainbow trout may have different biochemical compositions and these differences may contribute to differences in fillet yield and quality. The finding of Manor et al. (2015) supports the difference between the biochemical composition of female and male rainbow trout in the current study.

In this study, total SFA was highest in DF and lowest in DM fillets. Many studies have found that SFA levels in diploid fish decline throughout sexual development (Manor et al., 2012; Riberio et al., 2012; Cleveland et al., 2017). The study's C16:0 and C18:0 SFAs and C18:1 and C22:1 MUFAs had the highest concentrations. Studies with Salmonid species found higher amounts of C16:0 and C18:0 from SFAs and C16:1 and C18:1 from MUFAs (Haliloğlu et al., 2004; Wang et al., 2015). Triploid female fillets had greater MUFA levels, whereas diploid female fillets have lower C18:1n-9c levels, which is consistent with the findings of do Nascimento et al. (2017). Riberio et al. (2012) revealed that MUFA and C18:1n-9c were transferred from the fillers to the gonads during this phase, while Henderson et al. (1984) noted that fish require C18:1n-9c to spawn. These literature studies explain why the C18:1n-9 and MUFA values of the diploid group fillets in this study are lower than the C18:1-9 and MUFA values of the triploid group fillets. The EPA and DHA values of DF fillets was higher than the other groups fillets. Cleveland et al. (2017) reported that contrary to our findings, the EPA value is higher in triploid fish than diploid fish and the ploidy effect in fish affects the composition of fatty acids. Similar to Ribero et al. (2012)'s findings, the n-3 PUFAs (C18:3n-6, C20:3n-3, and C20:5n-3) were higher in diploid groups particularly DHA.

The atherogenicity (AI) and thrombogenicity (TI) indices show the relationship between saturated and unsaturated fatty acids in the assessment of cardiovascular diseases (Ghaeni et al., 2013). According to Łuczynska et al. (2017), the AI and TI levels should not be greater than 1.00 for human health. The hypocholesterolemic/ hypercholesterolemic index (H/H) the fatty acid ratio based on cholesterol metabolism (Fernandes et al., 2014) and the foods with high H/H index values (>3) are believed to be better for human health. All groups in this study had AI, TI, and H/H values that were in line with those in the literature (Fernandes et al., 2014; Devadowsaon et al.,

2016; Łuczynska et al., 2017; Kaya Öztürk et al., 2019) and at levels that are safe for human health.

Even among fish tissues, there are known to be differences in fat and fatty acid composition. The main component of fish used for human nutrition is typically the muscle, and the liver plays a significant role in lipid metabolism. Therefore, learning more about the fatty acid profiles of fish living in their natural ecosystems by looking at their muscle and liver tissues can be helpful (Kiessling et al., 2001; Rodriguez et al., 2004). Under culture conditions, the fatty acids in fish tissues often reflect the fatty acids in their diet. During the reproductive period, they must mobilize their energy reserves to meet the increased energy demand during gonadal growth (Memiş and Gün, 2004; Salem et al., 2006; Salem et al., 2007; Aussanasuwannakul et al., 2011; Ribeiro et al., 2011; Aussanasuwannakul et al., 2012; Manor et al., 2012). In this study, the predominant SFA in the livers of both sexes was C16:0 (Table 5). The fatty acid present in the second-highest concentration was C18:0. TF livers had a higher amount (9.15±0.01%) of C18:0 than DF livers (6.75±0.08%). Only DM livers contained the C17:0, C20:0, and C22:0. In the liver of both sexes and ploidy, C18:1n-9 was found to be the main MUFAs. This fatty acid was higher in the fillets of DM and DF, while higher levels were found in the liver of the TF. In many studies, C18:1n-9 was determined to be the dominant MUFAs in the livers of rainbow trout, regardless of sex and ploidy (Akpinar et al., 2009; Ozório et al., 2012; Taylor et al., 2019). Although they are cultured under the same conditions and fed with the same feed, the differences in C18:1n-9 fatty acids of livers are thought to be due to ploidy and sex differences. Among the n-6PUFAs, C18:2n-6t was the main n-6PUFAs in the liver. In terms of sexes, C18:2n-6t is the highest in DM; in terms of ploidy, it was high in DF livers. Akpinar et al. (2009) reported that the most common n-6 PUFA in livers was C20:4n-6 and the highest value was in male fish livers. The differences in the literature are thought to be due to the fatty acids in fish diets.

The nutrition of broodstock is an essential factor affecting fecundity, gametogenesis, and gamete quality. Many studies have been conducted on female fish during their reproductive period, from gonad development to egg quality, from the hatching period to larval quality (Sargent et al., 2002; Perez et al., 2007; Huang et al., 2010). It is also known that the composition of fatty acids in sperm is related to the composition of fatty acids in diets, and feeding is also effective on sperm quality in male broodstocks (Pustowka et al., 2000; Jeong et al., 2002; Perez et al., 2007). It has been reported that dietary C16:0, C18:1n-9, C20:4n-6, EPA, and DHA increase the amount of gonads in male broodstocks (Perez et al., 2007). Lahnsteiner et al. (2009) reported that high amounts of C14:0, C16:0, C18:1n-9, C18:2n-6, C18:3n-3, C20:4n-6, EPA, and DHA in rainbow trout sperm. In the current study, the mentioned fatty acids determined in sperm were high. The EPA and DHA fatty acids determined in sperm were higher than EPA and DHA values determined in diet and fillets inn the present study. This suggests that the fatty acids taken with the feed are spent on the formation of sperms.

Since their composition can affect the rate of fertilization, hatching, survival, and growth of fish larvae, fats and fatty acid research in particular have been used to evaluate egg quality (Tocher, 2010). Many fish species have demonstrated that PUFAs like C22:6n-3, C20:5n-3, and C20:4n-6 are crucial for both reproductive control and larval development (Izquierdo et al., 2001). A significant amount of long-chain n-3 PUFA, primarily C20:5n-3 and C22:6 n-3, is also present in fish eggs (Lu et al., 1979), reported that they play a positive role in preventing diseases (Lee et al., 2008). A high content of total PUFAs (51.07±0.01% of the total amount of fatty acids) was found in the fatty acid composition of DF gonads, with the contents of omega-3 (21.56±0.07%) and omega-6 (27.26±0.07%). The high sum of C18:3n-3, DHA, and EPA was primarily responsible for the higher proportion of total omega-3s in DF gonads. In the current study, the EPA+DHA value of the DF gonad was 18.43±0.06. Earlier research using the gonads of salmonid species revealed a higher value for this value (Ballestrazzi et al., 2003; Haliloğlu et al., 2003; Bekhit et al., 2009; Kalogeropoulos et al., 2012; Kowalska-Groralska et al., 2019; Murzina et al., 2019). In the present study, DHA and PUFA values of DF gonads were higher than those found in other tissues, and the SFA value was lower. In many studies, it has been emphasized that broodstocks spend SFA in gonad formation and accumulate PUFAs in their gonads (Cowey et al., 1985; Rennie et al., 2005; Cleveland et al., 2012; Mannor et al., 2014; Murray et al.,2018), and the present data are compatible with these studies.

Conclusion

In the study, a large portion of the energy received from feed was allocated to reproductive activities. While the fatty acid composition determined in the diploid and triploid trout fillets during the reproductive cycle was at similar values, significant differences were determined, especially in the fatty acid compositions of the gonads and livers. In conclusion, the comparison between the biochemical and fatty acid composition of fillets, livers, and gonads of rainbow trout with different ploidy and sex characteristics is further illuminated by these data.

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Consent to Publish

The authors agree with the study.

Author Contributions

The authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Associate Professor Dr. Birol BAKİ and Dr. Dilara KAYA ÖZTÜRK.

Declaration of interest

The authors declare that have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and materials

All data generated or analyzed during this study are included in this published article

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