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Effect of Different Concentrations of Canola Oil in Diets on Body Chemical Composition and Growth Performance of Nile Tilapia (*Oreochromis niloticus*, Linnaeus 1758)

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Abstract.- The study was conducted in order to investigate the effect of supplementing various concentrations of canola oil on the growth performance and body chemical composition of Nile tilapia (*Oreochromis niloticus*, Linnaeus 1758). In the present study, five different experimental diets were used. Control group was fed 100% fish oil (FO) while other groups in triplicate, each of 25 fish, weighing 10 g each on the average were fed varying concentrations of canola oil *viz.*, 25% (CO25), 50% (CO50), 75% (CO75) and 100% (CO100). There was no significant difference among the groups in terms of their growth performance at the end of the experiment (60 days). The better feed utilization was observed for the FO group ($P<0.05$) indicating higher protein efficiency ratios (PER) and lipid efficiency ratios (LER) than the other groups. The viscerosomatic index (VSI) and the hepatosomatic index (HSI) were not different among the groups ($P>0.05$). The highest protein content in whole body was determined for CO50 and the lowest lipid content was determined for the CO75 group. Total saturated fatty acid (SFA) content was the highest in CO75 (33.51%). The monounsaturated fatty acid (MUFA) level was higher in canola-fed groups than in FO. The total n-3 polyunsaturated fatty acid (PUFA) level was higher in FO (11.21%) than that in the canola-fed groups (between 6.26% and 8.27%). The ratio of n-3/n-6 was highest in FO group (2.16), and in all groups it was greater than 1. Our findings confirmed that there was no adverse effect of canola oil on growth performance of Nile tilapia. Furthermore the whole body fatty acid composition was balanced in the canola-fed groups.

Key words: Nile tilapia**,** *Oreochromis niloticus*, canola oil, fish growth, body chemical composition.

INTRODUCTION

Fish oil is a considerable source of energy in aquaculture feed owing to its rich omega-3 (n-3) series long-chain polyunsaturated fatty acid (LC-PUFA) content including eicosapentaenoic acid (EPA, 22:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) (Mulligan and Trushenski, 2013). However, due to the high cost and scarcity of fish oil, the utilization of alternative vegetable oils (VO) in aquaculture feeds have been more important in recent years. The fish oil (FO) in aquaculture feed was replaced with VO completely or partially in recent studies (Turchini *et al*., 2009). Despite the recession in FO production throughout the world, the tilapia production keeps expanding and therefore the use of alternative VOs, which are easily accessible and relatively cheaper than FO, has become inevitable in recent years (Ng, 2005). The Tilapia culture has done extensive or semi-intensive in some tropical and subtropical countries (Zahid *et al.*, 2013). In recent years, intensive tilapia production started in Konya, Turkey. world tilapia production was 4.5 million metric tons in 2011 (FAO, 2014) and it is expected to reach 8.9 million metric tons in 2020 (Tacon and Metian, 2008). It was reported that the VOs, which would act as suitable alternative sources to FO were linseed oil, palm oil (Ng, 2005) and other VO varieties that are rich in 18:2n-6 content such as soybean oil, corn oil sunflower oil canola/rapeseed oil and various palm oil products (Lim *et al*., 2001, 2011). The results on growth performance and feed utilization were especially promising for tilapia hybrids (*O. niloticus* × *O. aureus*) (Chou and Shiau, 1999), broodstock female Nile tilapia (Ng and Wang, 2011) and Nile tilapia (Ng *et al*., 2006; Szabo *et al.*, 2011) upon the partial or full replacement of FO with VO mixtures or specific VOs. On the other hand, a significant difference could not be observed for Nile tilapia

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(Yıldırım Aksoy *et al.*, 2007; Trushenski *et al*., 2009; Mulligan and Trushenski, 2013), red hybrid tilapia (Ng *et al*., 2013) and hybrid tilapia (*O. niloticus* × *O. aureus*) (Han *et al*., 2013). The performance of red hybrid tilapia fed on fish feed prepared using various palm oil products was similar to or better than red hybrid tilapia fed on fish feed prepared using FO (Ng *et al*., 2001; Bahurmiz and Ng, 2007). The fatty acid (FA) requirements and their capability to elongate and desaturate chains from n-6 and n-3 PUFAs to n-6 and n-3 LC-PUFAs facilitate the use of supplements of vegetable origin in feed mixtures for cultured tilapia. Additionally, relatively higher n-6 FAs content and lower n-3 LC-PUFAs (EPA and DHA) content was determined in the tilapia fillets fed with VO based products than those fed with FO based products (Lim *et al*., 2011). Owing to the important role of both EPA and DHA in human health, a balanced ratio of n-3/n-6 in cultured fish is a desirable trait (Steffens, 1997). Therefore, it is important to select the alternative sources of VO to be used in aquaculture feed carefully. Thrusenski *et al.* (2009) proposed the use of feed with high saturated fatty acid (SFA) and monounsaturated fatty acids (MUFA) content and low medium-chain (18-carbon) PUFA content in achieving the optimal FA composition of Nile tilapia. Canola oil is content has a high MUFA ratio (almost 50% of total FAs). Additionally, it has lower n-6 series FA content than almost all types of VOs with the exception of olive oil and palm oil (Glencross, 2009).

For this reason, the present study aims to determine the growth performance, feed utilization and body chemical composition of tilapia fed with feed in which the FO was replaced with canola oil in increasing ratios (0, 25, 50, 75 and 100%).

MATERIALS AND METHODS

Experimental design and feeding trial

This experiment was carried out in Dr. Nazmi Tekelioglu Freshwater Research Station, Faculty of Fisheries, Cukurova University, Adana, Turkey. Fifteen net cages (1x1x1m dimensions and 1x1cm mesh size) were fixed to a platform in the middle of the concrete pool (240 m^2 surface area and 2 m depth). The twenty five *Oreochromis niloticus* (initial mean weight; 10.00±0.98 g) juveniles were randomly stocked into the each net cages as three replicates. The fish were hand-fed to visual satiety three times a day (08:00, 12:30 and 17:00) over the course of experiment (60 days). Water quality parameters such as temperature and dissolved oxygen (OxyGuard Handy Polaris 2) were measured daily and pH was measured weekly (Lutron pH-207 HA). The oxygen level, water temperature and pH value were 5.9±1 mg/L, 23.3±1^oC and 7.5±1, respectively and water flow was 3 L/min during the experimental period.

Experimental feeds

Five iso-nitrogenic (30% crude protein) and iso-lipidic (12% crude lipid) diets were formulated . FO was replaced with canola oil (CO) at 0% (FO), 25% (CO25), 50% (CO50), 75% (CO75) and 100% (CO100) substitution levels. All the ingredients were finely-grounded, well mixed and made into pellets (2 mm in dimension) with a laboratory pellet machine. The diets were air dried at room temperature for 24 h. All diets were sealed in vacuum-packed bags and stored in freezer at -20°C until their used.

Sample collection and analytical methods

An initial sample of 30 fish from stock pond was taken at the begining of the experiment. At the end of trial, a sample of 15 fish from each cage was taken randomly. Proximate analysis of experimental diets, diet ingredients and whole body fish sample was carried out using standart AOAC methods (1990). Moisture content was determined by oven drying at 105°C until a constant weight, ash was determined by incineration at 550°C for 18 h and crude protein was determined (N×6.25) by the Kjeldhal method. Total lipid content was determined according to the Blingh and Dyer (1959) method.

The FA methyl esters of experimental diets and whole body fish samples were prepared using the method described by Ichiara *et al*. (1996) with a minor modification–through transmethylation using 2M KOH in methanol and *n*-heptane. The FAs were analysed by a GC Clarus 500 with autosampler

(Perkin Elmer, USA) equipped with a flame ionization detector and a fused silica capillary SGE column (30 m × 0.32 mm, ID × 0.25 μm, BP20 0.25 UM, USA). The oven was heated to 140°C, held for 5 min at this level, and raised to 200°C by 4°C.min^{-1} and to 220°C by 1°C min^{-1}, while the injector and the detector temperature were set at 220°C and 280°C, respectively. The sample size was 1 μl and the carrier gas was helium 16 psi with a split ratio of 1:100. FAs were identified by comparing the retention times of FAME with a Standard 37 component FAME mixture (Supelco). All analyses were performed three times.

Statistical analysis

All data were subjected to one-way analysis of variance (ANOVA) SPSS 15.0 Windows software package. Differences between the means were tested by Duncan's multiple range tests (Duncan, 1955). The level of significance was chosen at $P<0.05$ and the results are presented as mean±SD.

RESULTS

Proximate and FA composition of experimental diets

The formulation and the proximate composition of the experimental diets are presented in Table I. The proximate compositions of the diets were similar for all the experimental groups. The FA composition of the diets was representative of the FA composition of the different levels of canola oil (Table II). The major FA was 18:1n-9 and it was followed by 16:0 in the FO group. The FAs with the highest composition in the CO100 group were 18:1n-9 and 18:2n-6. The FO group had the richest content of SFA. Total monounsaturated FA (MUFA) levels were higher in canola groups in parallel with increasing ratios of canola oil. EPA and DHA contents were higher in the FO group than that in the CO groups. Therefore, the concentration of n-3PUFA was higher in the FO group in comparison to the canola-fed groups. Due to the high 18:2n-6 content of canola oil, the n-6 PUFA values in the canola-fed groups were higher than that in the FO group.

Table I.- Composition of experimental diets (% of dry matter).

Ingredients [a]	FO*	CO25*	CO50*	CO75*	CO100*
Fish meal	20	20	20	20	20
Soybean meal	30	30	30	30	30
Dextrin	22	22	22	22	22
Corn meal	12	12	12	12	12
Fish oil	8	6	4	2	0
Canola oil	0	2	4	6	8
CMC	1.5	1.5	1.5	1.5	1.5
DCP	1.5	1.5	1.5	1.5	1.5
Vit Mix [b]	2	2	2	2	2
Min Mix [c]	3	3	3	3	3
Proximate composition					
Moisture	9.8	10.3	9.8	10.2	10.2
Ash	7.7	7.7	7.5	7.7	7.6
Crude protein	30.3	30.3	30.5	30.2	30.2
Crude lipid	11.5	11.5	11.5	11.5	11.6
Crude fiber	6.2	6.2	6.3	6.5	6.5
NFE [d]	44.3	44.3	44.2	44.1	44.1

[a] All ingredients were obtained from local producers

[b] Vitamin mixture (g kg^{-1} vitamin mix): retinyl acetate, 1; cholecalciferol, 0.1; dl-a-tocopheryl acetate, 5; menadione, 1; thiamin–HCl, 1; riboflavin, 2; d-calcium panthothenate, 2; pyridoxine–HCl, 0.8; cyanocobalamine, 0.002; niacine, 4; choline, 200; ascorbic acid , 50; folic acid, 0.1; d-biotin, 0.5; mesoinositol, 30. All ingredients were diluted with a-cellulose.

[c] Mineral mixture (g kg^{-1} mineral mix): KCl, 60; KI, 0.04; CaHPO4.2H2O, 400; NaCl, 40; $CuSO4.5H_2O$, 3; $ZnSO4.7H_2O$, 4; CoSO4, 0.02; $FeSO4.7H_2O$, 20; $MnSO4.H_2O$, 3; CaCO3, 215; MgOH, 124; Na2SeO3, 0.03; NaF, 1

[d] Nitrogen-free extract (NFE) : 100- (protein+lipid+ash+fiber)

*FO, 100% fish oil; CO25, 25% canola oil; CO50, 50% canola oil; CO75, 75% canola oil; CO100, 100% canola oil.

Growth performance and feed utilization

All experimental diets were well taken by the fish. The survival rate was observed as 100% for all groups. The growth performance and the feed utilization parameters are shown in Table III. At the end of the experiment, there were no significant differences in the final weight and in the specific growth rate (SGR) among the experimental groups. The lowest feed conversion ratio (FCR) was determined for the FO group and whereas the canola-fed groups were similar to each other. The protein efficiency ratio (PER) and the lipid efficiency ratio (LER) were significantly higher in FO than in the other groups ($P<0.05$). The protein productive value (PPV) was significantly higher ($P<0.05$) in FO and in the CO50 group and the lowest PPV value was observed for the CO100

Table II.- Fatty acid composition (% of total fatty acid) of experimental diets.

Fatty acids	FO	CO25	CO50	CO75	CO100
14:0	8.34±0.20	5.59±0.02	5.82±0.01	4.14±0.14	3.15±0.01
16:0	20.53±0.34	18.27±0.14	15.45±0.16	12.73±0.05	9.91±0.06
18:0	6.33±0.20	6.09±0.04	5.81±0.04	5.79±0.05	5.33±0.13
16:1n7	6.30±0.28	5.73±0.26	5.21±0.08	3.97±0.49	2.53±0.01
18:1n9	21.29±0.63	34.61±0.29	39.35±0.31	46.01±0.50	52.18±0.09
18:1n7	1.79±0.03	ND	ND	ND	ND
20:1	1.27±0.02	1.42±0.04	1.52±0.07	1.37±0.02	1.51±0.03
18:2n6	4.95±0.09	7.18±0.05	9.86±0.05	12.76±0.06	14.44±0.06
18:3n6	0.20±0.01	0.05±0.01	0.15±0.01	0.13±0.01	0.11±0.05
18:3n3	0.92±0.09	0.96±0.01	0.89±0.01	1.20±0.01	1.12±0.01
18:4n3	0.08±0.01	0.09±0.01	ND	0.05±0.01	ND
20:4n6	0.88±0.04	0.62±0.02	0.51±0.02	0.31±0.02	0.13±0.02
20:3n3	0.17±0.01	ND	ND	ND	ND
20:5n3 EPA	8.73±0.12	5.03±0.025	4.10±0.10	2.20±0.20	1.00±0.02
22:5n3	0.61±0.01	0.45±0.01	0.40±0.01	0.37±0.02	0.37±0.02
22:6n3 DHA	9.98±0.15	7.67±0.15	6.33±0.12	4.47±0.06	3.10±0.12
SFA	35.20±0.60	29.95±0.05	27.08±0.20	22.66±0.13	18.39±0.14
MUFA	30.65±0.32	41.77±0.12	46.08±0.27	51.35±0.04	56.22±0.09
PUFA	26.53±0.15	21.54±0.04	22.24±0.10	21.49±0.20	20.37±0.28
n-3 PUFA	20.49±0.09	13.70±0.40	11.73±0.16	8.29±0.20	5.68±0.27
n-6 PUFA	6.04±0.06	7.84±0.06	10.52±0.06	13.20±0.04	14.69±0.01
n-3/n-6	3.39±0.04	1.75±0.06	1.12±0.02	0.63±0.02	0.39±0.02

ND: not detected
For other details see Table I.

Table III.- Growth performance, feed utilization of tilapia fed with different levels of canola oil for 60 days[a].

Parameters	FO	CO25	CO50	CO75	CO100
Initial weight (g)	10.00±0.93	10.00±0.82	10.00±0.90	10.00±0.89	10.00±0.91
Final weight (g)	35.87±3.96	35.17±5.04	35.65±5.30	34.90±6.10	35.17±5.20
SGR [b] (%/day)	2.13±0.02	2.10±0.05	2.12±0.03	2.08±0.03	2.10±0.04
FCR [c]	1.01±0.02[b]	1.15±0.04[a]	1.11±0.03[a]	1.13±0.04[a]	1.15±0.05[a]
PER [d]	3.26±0.06[a]	2.87±0.11[b]	2.96±0.08[b]	2.92±0.10[b]	2.87±0.11[b]
PPV [e] (%)	53.79±1.00[a]	51.42±2.10[ab]	53.99±1.42[a]	53.09±1.83[ab]	49.92±1.92[b]
LER [f]	8.60±0.15[a]	7.57±0.29[b]	7.86±0.20[b]	7.67±0.27[b]	7.48±0.30[b]
LPV [g] (%)	79.02±1.88[a]	62.62±2.72[bc]	65.27±1.81[b]	60.12±2.16[c]	59.60±2.35[c]

[a] Values are means ± SD of three replicates and values within the same row with different letters are significantly different ($P < 0.05$).
[b] Specific growth rate: SGR (%/day) = [Ln(final weight) - Ln(initial weight)] / (number of days) × 100.
[c] Feed conversion ratio: FCR= (dry feed fed) / (wet weight gain).
[d] Protein efficiency ratio: PER = (final weight) - (initial weight) / (mass of protein fed).
[e] Protein productive value: PPV(%) = (final body protein) - (initial body protein) / (protein intake) ×100.
[f] Lipid efficiency ratio: LER = (final weight-initial weight) / (mass of lipid fed).
[g] Lipid productive value: LPV(%) = (final body lipid) - (initial body lipid) / (lipid intake) × 100.

group. The lipid productive value (LPV) was significantly different among all groups (P <0.05). The FO group had the highest lipid utilization, whereas the CO100 group had the lowest lipid utilization with respect to the LPV values.

Proximate composition and body indices of fish

Significant differences were observed among groups in terms of the nutritional composition (P<0.05), but no significant differences were determined among the body indices (Table IV). The

Table IV.- Proximate composition and body indices of tilapia fed with different levels of canola oil for 60 days[a].

Parameters	Initial	FO	CO25	CO50	CO75	CO100
Moisture	74.43±0.58	69.05±0.64[b]	68.52±0.34[b]	68.95±0.69[b]	68.57±0.29[b]	70.34±0.34[a]
Protein	15.18±0.05	16.11±0.24[c]	17.13±0.03[a]	17.37±0.08[a]	17.31±0.16[a]	16.75±0.15[b]
Lipid	6.32±0.32	8.39±0.34[a]	7.72±0.25[b]	7.75±0.24[b]	7.40±0.42[b]	7.50±0.21[b]
Ash	3.68±0.33	4.52±0.23[a]	4.53±0.17[a]	4.55±0.25[a]	4.61±0.39[a]	3.63±0.31[b]
HSI [b]	1.16±0.17	1.87±0.15	1.63±0.10	1.57±0.12	1.66±0.18	1.75±0.19
VSI [c]	7.95±1.08	8.08±0.58	8.03±0.46	7.73±0.46	7.88±0.74	7.92±0.63

[a] Values are means ± SD of three replicates and values within the same row with different letters are significantly different ($P < 0.05$).
[b] Hepatosomatic index : HSI (%) = (liver weight) / (body weight) × 100.
[c] Viscerosomatic index : VSI (%) = (viscera weight) / (bodyweight) × 100.

Table V.- Whole body fatty acid composition (% of total fatty acid) of tilapia fed with different levels of canola oil for 60 days[a].

Fatty acids	Initial	FO	CO25	CO50	CO75	CO100
14:0	2.81±0.07	2.95±0.06[d]	3.16±0.02[c]	3.42±0.05[a]	3.24±0.02[b]	3.22±0.02[bc]
15:0	0.54±0.01	0.24±0.17	0.36±0.06	0.34±0.04	0.30±0.01	0.34±0.01
16:0	17.51±0.16	23.61±0.21[c]	22.56±0.12[d]	25.02±0.44[a]	24.47±0.09[b]	25.09±0.09[a]
18:0	4.71±0.07	6.08±0.12[a]	5.17±0.06[c]	4.16±0.08[d]	5.50±0.05[b]	3.56±0.10[e]
16:1n7	4.58±0.07	6.41±0.46[c]	6.44±0.08[c]	7.59±0.31[a]	6.00±0.09[c]	7.04±0.05[b]
18:1n9	23.45±0.19	28.85±0.18[d]	33.88±0.10[b]	31.37±0.38[c]	34.10±0.05[b]	35.48±0.09[a]
18:1n7	3.82±0.19	3.80±0.28[a]	3.82±0.03[a]	3.69±0.02[a]	3.72±0.07[a]	3.06±0.01[b]
20:1	3.36±0.12	1.72±0.03[e]	2.41±0.01[c]	2.94±0.14[a]	2.27±0.01[d]	2.77±0.01[b]
18:2n6	11.03±0.08	4.61±0.17[c]	4.46±0.04[c]	4.85±0.03[b]	4.21±0.04[d]	5.09±0.05[a]
18:3n6	0.16±0.01	0.08±0.02[ab]	0.10±0.01[a]	0.08±0.02[ab]	0.06±0.01[b]	0.07±0.01[b]
18:3n3	3.34±0.03	5.59±0.04[a]	2.03±0.01[c]	2.43±0.23[b]	1.86±0.01[c]	2.61±0.01[b]
18:4n3	0.56±0.01	0.50±0.01[a]	0.30±0.03[c]	0.36±0.03[b]	0.24±0.01[d]	0.33±0.01[bc]
20:4n6	1.16±0.01	0.50±0.02[a]	0.39±0.08[bc]	0.40±0.05[bc]	0.31±0.02[c]	0.44±0.03[ab]
20:3n3	0.10±0.01	0.08±0.01	0.07±0.02	0.08±0.02	0.07±0.01	0.08±0.03
20:5n3 EPA	1.76±0.12	0.50±0.36[b]	0.84±0.01[ab]	0.88±0.18[a]	0.61±0.01[ab]	0.69±0.01[ab]
22:5n3	3.42±0.04	1.78±0.02[a]	1.25±0.06[c]	1.38±0.15[bc]	1.10±0.01[d]	1.49±0.01[b]
22:6n3 DHA	6.21±0.05	2.77±0.04[b]	2.44±0.01[c]	2.65±0.31[bc]	2.39±0.01[c]	3.07±0.01[a]
SFA	25.58±0.17	32.88±0.15[b]	31.25±0.20[d]	32.94±0.58[b]	33.51±0.13[a]	32.21±0.10[c]
MUFA	35.21±0.38	40.69±0.63[d]	46.55±0.18[a]	45.60±0.55[bc]	46.09±0.05[ab]	45.34±0.10[c]
PUFA	27.74±0.13	16.41±0.46[a]	11.89±0.25[d]	13.10±0.48[c]	10.85±0.03[e]	13.87±0.08[b]
n-3 PUFA	15.39±0.04	11.21±0.28[a]	6.93±0.14[d]	7.77±0.44[c]	6.26±0.02[e]	8.27±0.02[b]
n-6 PUFA	12.35±0.09	5.19±0.18[b]	4.96±0.12[c]	5.33±0.06[b]	4.58±0.01[d]	5.60±0.08[a]
n-3/n-6	1.25±0.01	2.16±0.03[a]	1.40±0.01[cd]	1.46±0.07[bc]	1.37±0.01[d]	1.48±0.02[b]

[a] Values are means ± SD of three replicates and values within the same row with different letters are significantly different ($P < 0.05$).
For other details see Table I.

whole body protein content was higher in the canola-fed groups compared to that in the FO group, and the whole body lipid composition was higher in the FO group in comparison to the other groups. Body indices such as the hepatosomatic index (HSI) and the viscerosomatic index (VSI) were not significantly different among the groups (P>0.05).

FA composition of fish

Whole body FA compositions of fish including initial values are given in Table V. The whole body FA composition of tilapias, which were fed with canola oil supplemented feed for 60 days was shown to be affected by the new diet. The most dominant FA in all groups including the data for the

initial population was the FA 16:0 among the total SFAs, followed by 18:0 and 14:0. The total SFA content was significantly higher in CO75 group (33.51%) and followed by the FO and CO50 groups ($P<0.05$). The total MUFA content was determined to be significantly higher in canola-fed groups in comparison to that in the FO group ($P<0.05$). The highest 18:1n-9 value was determined for the CO100 group whereas the lowest value was determined for the FO group owing to the high 18:1n-9 content of canola oil. The total PUFA content and n-3 PUFA values were higher for the FO group in total body FA composition as it was the case for the test feed. The differences among the groups were significant for this value ($P<0.05$). A similar trend was observed for the n-6 PUFA composition and the highest value was obtained in CO100 group. However, the increase in n-6 PUFA content was not proportional to that of increasing canola oil content in the feed. The highest content for the CO100 group was followed by that for the FO and CO50 groups. The n-3/n-6 ratio was significantly different among the groups varying between 1.37 (CO75) and 2.16 (FO).

DISCUSSION

The effect of using alternative oils to replace FO in aquaculture feed has been investigated for a substantial amount of time. The present study was conducted to investigate the effect of replacing FO in Nile tilapia feed with canola oil in increasing ratios on the growth performance, feed utilization and body composition of the fish. The results of the study indicated that the growth performance of the groups were not significantly different ($P>0.05$). This result was in agreement with previously conducted studies on different tilapia species (Yıldırım-Aksoy *et al*., 2007; Trushenski *et al.*, 2009; Mulligan and Trushenski, 2013; Ng *et al*., 2013; Han *et al.*, 2013).

The FCR was determined to be similar for the groups utilizing canola oil in the present study, however, the feed utilization of the FO group was determined to be better. Previously conducted studies of 5 months or longer duration reported that the differences in the FCR value was determined to be statistically insignificant for red tilapia upon the use of VOs to replace FO in the feed although a slightly better feed utilization was observed for the fish utilizing the feed containing FO (Bahurmiz and Ng, 2007; Ng *et al*., 2013). Mulligan and Trushenski (2013) reported that the group that was supplemented with palm oil had improved feed utilization over the groups supplemented with either FO or other VOs although no difference was observed in growth performance between the VO and FO supplemented groups in their study on Nile tilapia. Evaluation of the criteria regarding feed utilization and fish growth indicated that all groups in the present study displayed similar growth performances indicating the absence of any problems regarding the utilization of the feed supplemented with canola oil by the tilapia groups, utilizing the feed effectively resulting in a satisfactory growth performance. Similar conclusions were drawn in other studies that were mentioned above and the utilization of the feed comprised of different types of VO were concluded not affect growth adversely.

Differences were observed among the groups under investigation in the present study in terms of the utilization of the protein and lipids in the feed as well as the body nutritional compositions. The PER and LER were higher for the FO group than any one of the canola-fed groups whereas the group utilizing protein the best was CO50, followed by FO, CO75 and CO25. Although the canola-fed groups utilized proteins in the feed better, the LPV, indicating the extent of the utilization of the lipids from the feed was lower than that determined for the FO group. Complementarily, the body protein content of the FO group was lower than that of the canola-fed groups and the body lipid content was determined to be high. The relationship between the utilization of proteins and lipids from the feed and the body protein and lipid content of the fish was observed to be similar to other previously conducted studies (Lim *et al*., 2001; Bahurmiz and Ng, 2007; Turchini *et al*., 2011; Mulligan and Trushenski, 2013). Taking the lower feed conversion ratio for the FO group into consideration, the PER and LER of the feed was determined to be higher for the same group as expected. On the other hand, the canola-fed groups were determined to more effectively utilize the protein in the feed and were also observed to

store protein better. The lipid was used more in these groups leaving a lower lipid composition of the body than that of the FO group. The LPV was similarly low in canola-oil fed groups clearly indicating the utilization of lipids by the fish for growth and using protein for storage (Lim *et al*., 2001; Turchini *et al*., 2011). Juvenile fish were monitored in the present study and a difference among the groups was not observed by the end of two months in the growth performance and the body index values (HSI and VSI), which would also complement each other. These results are in agreement with previously conducted studies in which the feed were supplemented with VOs instead of FO and no significant difference in growth was observed (Yıldırım-Aksoy *et al*., 2007; Trushenski *et al.,* 2009; Mulligan and Trushenski, 2013; Ng *et al*., 2013; Han *et al.,* 2013). However, the VSI value of the broodstock female tilapia were also determined to be different along with their growth performance and this interaction was reported to be effective on the egg production and gonad weight of the female tilapia (Ng and Wang, 2011).

The total body FA content of the fish was affected by the varying content of canola oil present in the feed and displayed similar profiles in all cases with the exception of a few FAs. The SFA values of the fish were increasingly affected by their respective values in the feed composition. Especially palmitic acid (C16:0), an important component in SFA was determined to be stored. Similar to our current findings, the capability of the fish to store saturated FAs regardless of the SFA values determined for the feed was previously reported (Huang *et al*., 1998, 2008; Ng *et al*., 2001; Bahurmiz and Ng, 2007; Han *et al*., 2013). The oleic acid (18:1n-9) content of the feed, and consequently the total MUFA content of the feed was increased with increasing ratios of canola oil addition, resulting in a considerable difference between the groups FO and CO100. However, this difference was observed to be less pronounced in the body of the fish although the highest MUFA values were still determined for the canola oil-fed groups. Similar findings were reported in previous studies in which canola oil was used (Huang *et al*., 1998, 2008; Mulligan and Trushenski, 2013; Lee *et al*., 2013).

It is desirable to have a balanced n-3/n-6 composition in the nutrient composition of fish. Because of this reason, previous studies reported a lowering of the nutritional content of the fish that were fed with high content of VO resources having high n-6 series of FAs content (Han *et al.,* 2013). A number of studies reported lower EPA, DHA and n-3/n-6 ratios in the body composition of the fish that were fed with VO-based diets rather than FO-based diets (Trushenski *et al.,* 2009; Mulligan and Trushenski, 2013; Han *et al.,* 2013). Despite the similarity of the results obtained in the present study and previously conducted studies, the n-3 PUFA content of the body composition of the CO100 group was determined to be higher in comparison to their value in the feed composition. On the other hand, the n-6 series of FAs content displayed an increasing trend with increasing canola oil content of the feed although this increase was not reflected in the body composition of the fish, yielding similar compositions for the fish fed FO or canola oil. Tilapia and carp were reported to require more n-6 PUFAs than n-3 PUFAs in order to be able to achieve maximum growth (NRC, 1993). The n-6 PUFAs, specifically 18:2n-6 was utilized very efficiently by the canola-fed groups in the present study and as a result, this was reflected on the growth performance of the fish. Furthermore, the n-3/n-6 ratio was determined to be higher than 1 for all canola-fed groups thus rendering them acceptable in terms of nutritional value.

CONCLUSION

In conclusion, the utilization of canola oil in tilapia feed to replace FO did not affect the growth of the fish adversely. Although the utilization of the feed was slightly better in the FO group than in the canola-fed groups, the body chemical composition of the tilapia fish displayed a balanced profile of FA composition in the study.

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