Influence of diets enriched with different vegetable oils on the performance and fatty acid profile of Nile tilapia (*Oreochromis niloticus*) fingerlings

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ABSTRACT. The fatty acid profile of the carcass of Nile tilapia (*Oreochromis niloticus)* fingerlings fed diets enriched with different soybean, canola, sunflower, flaxseed, rice, and corn oils was examined. The results showed that palmitic (16:0), stearic (18:0), oleic (18:1 n-9), linoleic (18:2 n-6), and linolenic (18:3 n-3) acids were the predominant fatty acids in all vegetable oil, diet, and fish carcass samples analyzed. Flaxseed oil presented the highest amount of linolenic acid (45.63%), while the other vegetable oils had percentages lower than 5.0%. Neither of the vegetable oils used affected the performance of tilapia fingerlings and they can be utilized in Nile tilapia fingerling diets. However, in relation to the carcass fatty acid profile, the use of flaxseed oil in Nile tilapia fingerling diet is recommended.

Key words: tilapia, *Oreochromis niloticus*, fatty acids, vegetable oils.

RESUMO. Influência das dietas contendo diferentes óleos vegetais na performance e perfil em ácidos graxos de alevinos de tilápia do Nilo (*Oreochromis niloticus*). Foram examinados o perfil de ácidos graxos nas carcaças de alevinos de tilápia do Nilo (*Oreochromis niloticus)* alimentados com dietas enriquecidas com diferentes óleos vegetais (soja, canola, girassol, linhaça, arroz e milho). Os resultados indicaram que o ácido palmítico (16:0), esteárico (18:0), oléico (18:1n-9), linoleico (18;2n-6) e linolênico (18:3n-3) foram os ácidos predominantes em todas as frações analisadas (no óleo vegetal, dietas e carcaças dos peixes). O óleo de linhaça apresentou o maior valor de ácido linolênico (45,63%), quanto aos outros óleos vegetais tiveram uma percentagem menor que 5,0%. Todos os óleos vegetais não afetaram a performance dos alevinos e podem ser utilizados nas dietas, entretanto, em relação a qualidade nutricional o uso do óleo de linhaça é recomendado em dietas de alevinos de tilápia.

Palavras-chave: tilápia, *Oreochromis niloticus*, fatty acids, óleos vegetais.

Introduction

Tilapia is widely cultured in tropical and subtropical regions of the world and it constitutes the third most farmed finfish, after only carps and salmonids, respectively (El-Sayed, 1999).

All animal species require nutrients and energy for their support, growth, and reproduction. Diets supply energy through lipids, protein, and carbohydrates. The lipids used in fish diets are important sources of energy and essential fatty acids.

According to Mckenzie (2001), the lipid composition of the diet is transferred to *in vivo* fish; therefore, it results in different fatty acid profiles. Thus, it is of nutritional interest to improve the n-3 fatty acid profile through the use of a lipid source.

In recent years, lipids from fish muscle have received much attention as a source of unsaturated fatty acid in human diet. Epidemiological studies have indicated an inverse correlation between heart diseases and fish consumption (Archer *et al.*, 1998). Studies have shown that due to the high content of long-chain n-3 polyunsaturated fatty acids of fish, mainly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), the consumption of fish, and especially of its fatty acids, can be related to the prevention of cardiovascular diseases and can be used in their treatment. As these acids cannot be synthesized by humans, they must be obtained through diet (Coelho *et al.*, 1999; Schacky, 2000; Haliloglu *et al.*, 2004; Rasoarahona *et al.*, 2005).

The low incidence of coronary heart disease in Japan and Greenland, where fish is a staple food, suggest that the consumption of fish may protect against such disease (Ascherio *et al.*, 1995). According to Harris *et al.* (2004), the risk of death from cardiovascular diseases can be reduced through nutritionally achievable intakes of n-3 fatty acids. Rogers *et al.* (2004) reported some evidence that birth weight and length of gestation are increased among communities with a high intake of sea foods such as the Faroe and Orkney Islands, which may be attributed to n-3 fatty acids. Fish oils are important sources of EPA and DHA. Their role as precursors in the biosynthesis of eicosanoids explains many of the observed effects on health and diseases as well. Therefore, the ingestion of EPA and DHA from fish or fish oil leads to: 1) decreased production of prostaglandin E_2 metabolites; 2) decreased concentration of thromboxane A_2, an effective platelet aggregator and vasoconstrictor; 3) decreased formation of leukotriene B_4, an inflammation inductor; 4) increased concentration of thromboxane A_3, a weak platelet aggregator and vasoconstrictor; and 5) increased concentration of prostacyclin PGI3 without a decrease in PGI2 (both PGI2 and PGI3 are active vasodilators and inhibitors of platelet aggregation) (Connor, 2000; Simopoulos, 1999).

Omega 3 and 6 fatty acids are not inter-convertible in the human body and they are important components of practically all cell membranes. Therefore, the polyunsaturated fatty acid composition of cell membranes is dependent on dietary intake to a great extent (Simopoulos, 1991). Several studies have investigated the effect of diets on fatty acid profile (Méndez *et al.*, 1996; Bruce *et al.*, 1999; Farndale *et al.*, 1999; Fontagné *et al.*, 1999; Mourente *et al.*, 1999; Støttrup *et al.*, 1999; Han *et al.*, 2000; Navarro and Villanueva, 2000; Chou *et al.*, 2001; Ng *et al.*, 2001; Justi *et al.*, 2003; Maina *et al.*, 2003; Visentainer *et al.*, 2005).

In this research, the performance of Nile tilapia (*Oreochromis niloticus*) fingerlings fed diets enriched with different vegetable oils and the fatty acid profile of the carcass was examined.

Material and methods

Sampling

Three hundred fish with initial weight of 0.26±0.01 g distributed in 30 hapa nets were submitted to six treatments and five repetitions. Fish were fed six times a day. After 60 days, the fish were slaughtered and their carcasses, without head, fins, and viscera, were conditioned in polyethylene bags with gaseous nitrogen at -18°C until analysis, when the samples were unfrozen to the room temperature, ground, and homogenized. The experiments were carried out in the Aquaculture Laboratory of the Biology Department of Universidade Estadual de Maringá, Paraná State, Brazil.

Experimental diets

Six isocaloric (3140 kcal kg^{-1}) diets containing 5% soybean, canola, sunflower, flaxseed, rice, and corn oils were prepared as shown in Table 1. Table 2 presents the proximate composition of the feeds.

Table 1. Compositions of feeds*.

Ingredients (%)		Nutrients	
Corn	9.23	Available energy (kcal kg^{-1})	3140.00
Wheat meal	19.38	Available phosphorus (%)	0.60
Soybean meal	56.30	Calcium (%)	1.20
Fish meal	5.00	Crude fiber (%)	6.20
Sugar cane bagasse	1.47	Fat (%)	7.00
Bicalcium phosphate	2.33	Methionine + cystine (%)	1.12
Limestone	0.27	Lysine (%)	2.06
Vegetable oil**	5.00	Crude protein (%)	32.00
Salt	0.50		
Premix***	0.50		
Antioxidant	0.02		

*Data provided by Aquaculture Laboratory, Department of Biology of Universidade Estadual de Maringá; based on values of Rostagno *et al.* (1994); **Different vegetable oils; ***Mineral and vitaminic supplement.

Table 2. Chemical composition of feeds enriched with different vegetable oils*.

Parameter	Moisture (%)	Ash (%)	Protein (%)	Lipids (%)
Soybean	6.12^{a}±0.07	8.25^{a}±0.03	33.20^{a}±0.38	7.96^{a}±0.09
Canola	5.34^{b}±0.10	8.42^{a}±0.08	33.51^{a}±0.19	7.33^{a}±0.00
Sunflower	5.27^{b}±0.14	8.47^{a}±0.08	34.50^{b}±0.63	7.57^{a}±0.41
Flaxseed	5.15^{b}±0.32	8.32^{a}±0.16	$35.12^{b,c}$±0.18	8.00^{a}±0.69
Rice	$5.64^{a,b}$±0.17	8.25^{a}±0.02	35.73^{c}±0.10	7.94^{a}±0.16
Corn	5.22^{b}±0.19	8.28^{a}±0.04	$35.21^{b,c}$±0.11	7.41^{a}±0.09

*Average of five samples determined in triplicate and standard deviations. Averages followed by different letters in same column are significantly different ($P < 0.05$).

Analysis

Moisture and ash contents were determined gravimetrically by desiccation at 105°C and by incineration in oven at 600°C, respectively. The crude protein content was obtained by the Kjeldahl method, according to Cunniff (1998).

The total lipids were extracted by the Bligh and Dyer (1959) method and the fatty acid methyl esters (FAME) were prepared by methylation of the triacylglycerols as described by ISO (1978).

FAME were analyzed in a Shimadzu 14A (Japan) gas chromatograph equipped with a flame ionization detector (FID) fit with a fused silica capillary column (50 m, 0.25 mm i.d. and 0.20 μm of Carbowax 20M). Column temperature was programmed to 2°C min^{-1}

from 150ºC to 240ºC. Injector and detector temperatures were 220ºC and 245ºC, respectively. The carrier gas was hydrogen (1.2 mL min^{-1}) and the make-up gas was nitrogen (30 mL min^{-1}). The split used was 1/100. Peak areas were determined using the CG-300 computing integrator and FAME were identified by comparison with the retention times of known standards from Sigma (USA).

Statistical analysis

The results were submitted to variance analysis (ANOVA) at 5% significance level using Statistica (1996) software (version 5.1). The mean values were compared by Tukey's test.

Results and discussion

Tilapia fingerling performance and carcass characteristics

Table 3 shows the final weight, weight gain, apparent feed:gain, and eviscerated fish and carcass yields. The results were not significantly different ($P>0.01$) in relation to the different oils in diets.

Table 3. Average performance characteristics of Nile tilapia fingerlings fed diets containing different vegetable oils*.

Characteristics	Vegetable oils added to diets						CV (%)
	Soybean	Canola	Sunflower	Flaxseed	Rice	Corn	
Initial weight (g)	0.26	0.26	0.26	0.26	0.26	0.26	2.02
Final weight (g)	5.34	6.00	6.07	5.66	5.93	5.65	12.26
Weight Gain (%)	1921.79	2170.17	2194.96	2034.35	2151.81	2038.23	12.46
Medium length (cm)	6.67	6.94	6.84	6.98	6.68	6.87	6.52
Apparent feed:gain	1.20	1.11	1.15	1.23	1.06	1.18	11.44

*Data provided by Aquaculture Laboratory, Department of Biology of Universidade Estadual de Maringá, Paraná State; values in the same line are not significantly different by Tukey's test ($P > 0.01$).

Proximate carcass composition of Nile tilapia (*Oreochromis niloticus*)

The addition of different vegetable oils to the diets of tilapia fingerlings did not result in significant differences ($P>0.05$) in relation to carcass moisture, ash, and total lipid contents. However, differences ($P<0.05$) were verified for crude protein, as shown in Table 4.

Table 4. Chemical composition of the carcass of tilapia, *Oreochromis niloticus* in the initial phase of development (fingerlings) submitted to diets enriched with different vegetable oils.

Parameter	Moisture (%)	Ash (%)	Protein (%)	Lipids (%)
Soybean	77.96^{a}±0.22	2.15^{a}±0.01	17.09^{a,b,c}±0.09	1.90^{a}±0.14
Canola	78.31^{a}±0.98	1.98^{a}±0.50	17.57^{b}±0.28	2.06^{a}±0.28
Sunflower	76.71^{a}±0.05	2.10^{a}±0.22	17.71^{b}±0.25	1.77^{a}±0.04
Flaxseed	77.41^{a}±0.28	1.91^{a}±0.01	17.76^{b}±0.16	1.95^{a}±0.19
Rice	77.94^{a}±0.71	2.01^{a}±0.13	17.32^{a,b,c}±0.13	1.72^{a}±0.15
Corn	77.82^{a}±0.68	1.99^{a}±0.01	17.06^{a,c}±0.25	1.74^{a}±0.04

Results are means of five sample measurements determined in triplicate. Averages followed by different letters in same column are significantly different ($P < 0.05$) by Tukey's test.

Fatty acids in oils, feeds, and Nile tilapia carcasses

Table 5 shows the fatty acid profiles of the vegetable oils used throughout the experiments. The total saturated fatty acid (SFA) contents ranged from 7.31% for canola oil to 21.56% for rice oil. The highest percentage of SFA was 16:0 (palmitic), followed by 18:0 (stearic) for all vegetable oils analyzed. Among the monounsaturated fatty acids (MUFA), 18:1 n-9 (oleic) had the highest content (from 22.28 to 57.71%) with the highest total of MUFA for canola oil (63.96%) and the lowest for soybean oil (25.41%). The total polyunsaturated fatty acid (PUFA) concentrations were the highest for flaxseed (60.58%) and soybean (60.38%) oils and the lowest for canola oil (28.74%).

Table 5. Fatty acid (FA) profile of the vegetable oils added to feeds.

FA	Soybean	Canola	Sunflower	Flaxseed	Rice	Corn
C14:0	0.07^{a}±0.00	0.06^{a}±0.01	0.08^{a}±0.00	0.05^{a}±0.01	0.25^{b}±0.04	ND
C16:0	10.86^{a}±0.15	5.11^{b}±0.06	6.66^{c}±0.12	6.14^{c}±0.05	19.45^{d}±0.35	12.87^{e}±0.35
C16:1n-9	0.09^{a}±0.00	0.20^{b}±0.01	0.09^{a}±0.00	0.11^{a}±0.01	0.17^{b,c}±0.03	0.13^{a,c}±0.01
C17:0	0.08^{a}±0.01	ND	ND	ND	ND	0.07^{c}±0.00
C18:0	3.20^{a}±0.01	2.15^{b}±0.01	4.06^{c}±0.01	4.76^{d}±0.00	1.86^{e}±0.07	2.14^{b}±0.08
C18:1n-9	22.28^{a}±0.05	57.71^{b}±0.15	30.30^{c}±0.01	25.62^{d}±0.13	40.24^{e}±0.04	34.05^{f}±0.21
C18:1n-7	1.54^{a}±0.06	2.97^{b}±0.05	0.72^{c}±0.04	1.16^{d}±0.01	0.88^{c}±0.03	0.70^{c}±0.06
C18:2n-6	54.74^{a}±0.09	22.45^{b}±0.04	55.93^{c}±0.26	14.95^{d}±0.06	33.69^{e}±0.25	48.03^{f}±0.04
C19:1n-9	ND	0.48±0.01	ND	ND	ND	ND
C18:3n-3	5.64^{a}±0.02	6.28^{b}±0.01	0.41^{c}±0.01	45.63^{d}±0.11	1.56^{e}±0.07	0.82^{f}±0.02
C20:1n-11	0.41^{a}±0.00	0.75^{b}±0.04	0.42^{a}±0.00	0.26^{c}±0.01	0.74^{b}±0.00	0.58^{d}±0.02
C20:1n-9	0.21^{a,d}±0.00	1.21^{b}±0.03	0.17^{c}±0.03	0.41^{a,d}±0.01	0.57^{d}±0.11	0.27^{a,c}±0.01
C22:1n-11	0.42^{a}±0.01	0.33^{b}±0.00	0.92^{c}±0.04	0.20^{d}±0.01	0.24^{d}±0.00	0.18^{d}±0.02
C22:1n-9	ND	0.14^{a}±0.01	ND	0.46^{b}±0.01	ND	ND
C24:1n-9	0.12^{a}±0.01	0.16^{a}±0.00	0.24^{a}±0.01	0.21^{a}±0.03	0.35^{a}±0.02	0.17^{a}±0.01
SFA	14.21^{a}±0.15	7.31^{b}±0.07	10.80^{c}±0.12	11.00^{c}±0.05	21.56^{d}±0.36	15.08^{a}±0.36
MUFA	25.41^{a}±0.08	63.96^{b}±0.17	32.86^{c}±0.07	28.41^{d}±0.13	43.19^{e}±0.13	36.07^{f}±0.22
PUFA	60.38^{a}±0.09	28.74^{b}±0.04	56.33^{c}±0.26	60.58^{a}±0.13	35.25^{d}±0.26	48.85^{e}±0.05
n-3	5.64^{a}±0.02	6.28^{b}±0.01	0.41^{c}±0.01	45.63^{d}±0.11	1.56^{e}±0.07	0.82^{f}±0.02
n-6	54.74^{a}±0.09	22.45^{b}±0.04	55.93^{c}±0.26	14.95^{d}±0.06	33.69^{e}±0.25	48.03^{f}±0.04
PUFA/SFA	4.25^{a}±0.04	3.93^{b}±0.04	5.22^{c}±0.06	5.51^{d}±0.03	1.64^{e}±0.03	3.24^{f}±0.08
n-6/n-3	9.70^{a}±0.04	3.57^{a,c}±0.01	136.41^{b}±3.74	0.33^{c}±0.00	21.64^{d}±1.03	58.57^{e}±1.24

Results expressed as percentage of the total FA. Values are mean ± standard deviation for five samples and triplicate analyses. SFA = total saturated FA; MUFA = total monounsaturated FA; PUFA = total polyunsaturated FA; n-3 = total omega-3 FA; n-6 = total omega-6 FA; ND = not detected. Averages followed by different letters in same line are significantly different ($P<0.05$) by Tukey's test.

In relation to PUFA, it could be observed that flaxseed oil showed the highest percentage for 18:3 n-3 (linolenic, 45.63%). However, 18:2 n-6 (linoleic) varied from 14.95% for flaxseed oil to 55.93% for sunflower oil. Soybean, canola, sunflower, flaxseed, rice, and corn oils presented the following PUFA/SFA ratios: 4.25, 3.93, 5.22, 5.51, 1.64, and 3.24, respectively. Nevertheless, in relation to n-6/n-3, flaxseed oil stood out with a value of 0.33.

The fatty acid composition of feeds enriched with the different oils can be observed in Table 6. Similar behaviors were observed for oil and feed PUFA/SFA and n-6/n-3 ratios. Therefore, the feed containing flaxseed oil presented the best values, standing out for n-6/n-3 ratio (0.74).

Table 7 shows that 16:0 and 18:0 are predominant SFA in all samples and that 16:0 had the highest percentage. In relation to MUFA, 18:1 n-9 had the highest percentage while for PUFA, the most representative was 18:2 n-6, which was also the acid with the highest percentage among all detected acids. In addition, it can be observed that the carcass of fingerlings fed the flaxseed oil-enriched diet presented a predominant percentage of acid 18:3 n-3 (12.51%) in relation to those of fingerlings fed the other diets. Table 7 also shows that the PUFA concentrations of all oils varied significantly from 31.97% (canola) up to 44.66% (sunflower). For MUFA, the results were more significant for canola oil (46.08%) while for the others, this summation was approximately constant, around 37%.

Table 6. Fatty acid (FA) profile of feed enriched with different vegetable oils.

FA	Soybean	Canola	Sunflower	Flaxseed	Rice	Corn
14:0	$0.24^{a}\pm0.02$	$0.21^{b}\pm0.00$	$0.23^{a,b}\pm0.00$	$0.22^{a,b}\pm0.00$	$0.34^{c}\pm0.00$	$0.20^{b}\pm0.01$
16:0	$13.45^{a}\pm0.08$	$8.57^{b}\pm0.00$	$9.74^{c}\pm0.04$	$9.81^{c}\pm0.09$	$18.41^{d}\pm0.01$	$14.05^{e}\pm0.11$
16:1n-7	$0.31^{a}\pm0.02$	$0.36^{b}\pm0.01$	$0.30^{a}\pm0.00$	$0.32^{a,c}\pm0.00$	$0.35^{b,c}\pm0.00$	$0.33^{a,b}\pm0.01$
17:0	$0.13^{a}\pm0.01$	$0.07^{a}\pm0.04$	$0.10^{a}\pm0.00$	$0.11^{a}\pm0.00$	$0.10^{a}\pm0.00$	$0.13^{a}\pm0.01$
18:0	$3.66^{a}\pm0.02$	$2.50^{b}\pm0.00$	$3.90^{c}\pm0.02$	$4.45^{d}\pm0.01$	$2.28^{e}\pm0.02$	$2.42^{b}\pm0.01$
18:1n-9	$22.93^{a}\pm0.10$	$46.94^{b}\pm0.12$	$27.07^{c}\pm0.14$	$24.21^{d}\pm0.02$	$34.22^{e}\pm0.00$	30.01 ± 0.01
18:1n-7	$1.61^{a}\pm0.01$	$2.61^{b}\pm0.03$	$0.95^{c}\pm0.02$	$1.32^{d}\pm0.02$	$1.13^{e}\pm0.00$	$0.95^{c}\pm0.02$
18:2n-6	$50.49^{a}\pm0.06$	$29.78^{b}\pm0.04$	$53.74^{c}\pm0.11$	$24.74^{d}\pm0.08$	$37.85^{e}\pm0.01$	$48.13^{f}\pm0.07$
18:3n-9	$0.36^{a}\pm0.00$	$0.12^{b}\pm0.00$	$0.23^{c}\pm0.01$	$0.10^{b}\pm0.00$	$0.12^{b}\pm0.01$	$0.20^{c}\pm0.01$
19:1n-9	$0.43^{a}\pm0.00$	$0.34^{b}\pm0.01$	ND	ND	ND	ND
18:3n-3	$4.42^{a}\pm0.04$	$5.82^{b}\pm0.03$	$1.49^{c}\pm0.00$	$32.72^{d}\pm0.01$	$2.87^{e}\pm0.06$	$1.87^{f}\pm0.01$
20:1n-11	$0.44^{a}\pm0.02$	$0.59^{b}\pm0.00$	$0.42^{c}\pm0.01$	$0.30^{d}\pm0.02$	$0.64^{b}\pm0.00$	$0.50^{a}\pm0.00$
20:1n-9	$0.27^{a}\pm0.00$	$0.97^{b}\pm0.04$	$0.24^{a}\pm0.00$	$0.41^{c}\pm0.00$	$0.47^{c}\pm0.00$	$0.31^{a}\pm0.00$
20:5n-3	$0.19^{a}\pm0.00$	$0.18^{a}\pm0.00$	$0.19^{a}\pm0.01$	$0.19^{a}\pm0.00$	$0.19^{a}\pm0.00$	$0.18^{a}\pm0.00$
22:1n-11	$0.46^{a}\pm0.00$	$0.33^{b}\pm0.01$	$0.87^{c}\pm0.01$	$0.25^{d}\pm0.01$	$0.29^{e}\pm0.00$	$0.22^{f}\pm0.01$
22:1n-9	$0.14^{a}\pm0.01$	$0.18^{b}\pm0.01$	$0.15^{a}\pm0.00$	$0.43^{c}\pm0.01$	$0.14^{a}\pm0.00$	$0.12^{a}\pm0.00$
22:6n-3	$0.30^{a}\pm0.01$	$0.30^{a}\pm0.01$	$0.30^{a}\pm0.00$	$0.32^{a}\pm0.02$	$0.30^{a}\pm0.02$	$0.30^{a}\pm0.01$
24:1n-9	$0.17^{a}\pm0.00$	$0.13^{a,b}\pm0.00$	$0.10^{b,c}\pm0.02$	$0.09^{b,c}\pm0.00$	$0.31^{d}\pm0.01$	$0.08^{c}\pm0.01$
SFA	$17.48^{a}\pm0.08$	$11.34^{b}\pm0.04$	$13.97^{c}\pm0.04$	$14.59^{d}\pm0.10$	$21.12^{e}\pm0.02$	$16.80^{f}\pm0.11$
MUFA	$26.76^{a}\pm0.11$	$52.46^{b}\pm0.13$	$30.09^{c}\pm0.15$	$27.33^{d}\pm0.04$	$37.55^{e}\pm0.01$	$32.52^{f}\pm0.03$
PUFA	$55.76^{a}\pm0.07$	$36.20^{b}\pm0.05$	$55.94^{a}\pm0.11$	$58.08^{c}\pm0.08$	$41.33^{d}\pm0.07$	$50.68^{e}\pm0.07$
n-3	$4.91^{a}\pm0.04$	$6.30^{b}\pm0.04$	$1.98^{c}\pm0.01$	$33.23^{d}\pm0.03$	$3.36^{e}\pm0.06$	$2.35^{f}\pm0.01$
n-6	$50.49^{a}\pm0.06$	$29.78^{b}\pm0.04$	$53.74^{c}\pm0.11$	$24.74^{d}\pm0.08$	$37.85^{e}\pm0.01$	$48.13^{f}\pm0.07$
PUFA/SFA	$3.19^{a}\pm0.02$	$3.19^{a}\pm0.01$	$4.01^{b}\pm0.02$	$3.98^{b}\pm0.03$	$1.96^{c}\pm0.00$	$3.02^{d}\pm0.02$
n-6/n-3	$10.28^{a}\pm0.09$	$4.73^{b}\pm0.03$	$27.15^{c}\pm0.17$	$0.74^{d}\pm0.00$	$11.27^{e}\pm0.21$	$20.49^{f}\pm0.08$

Results expressed as percentage of total FA. Values are mean ± standard deviation of five samples and triplicate analyses. SFA = total saturated FA; MUFA = total monounsaturated FA; PUFA = total polyunsaturated FA; n-3 = total omega-3 FA; n-6 = total omega-6 FA; ND = not detected. Averages followed by different letters in same line are significantly different ($P<0.05$), by Tukey's test.

Table 7. Fatty acid (FA) profile of tilapia *Oreochromis niloticus* carcass at initial phase of fingerlings submitted to diets enriched with different vegetable oils.

FA	Soybean	Canola	Sunflower	Flaxseed	Rice	Corn
14:0	$1.03^{a}\pm0.14$	$1.13^{a}\pm0.04$	$1.02^{a}\pm0.06$	$1.07^{a}\pm0.02$	$1.04^{a}\pm0.03$	$0.91^{a}\pm0.01$
I16:0	$0.22^{a}\pm0.04$	$0.23^{a}\pm0.00$	$0.22^{a}\pm0.00$	$0.22^{a}\pm0.01$	$0.21^{a}\pm0.02$	$0.20^{a}\pm0.01$
16:0	$17.75^{a}\pm0.70$	$15.50^{b}\pm0.13$	$16.36^{b}\pm0.21$	$16.8^{a,b}\pm0.22$	$18.95^{a,c}\pm0.38$	$18.29^{a,c}\pm0.08$
16:1n-9	$0.27^{a}\pm0.04$	$0.48^{b}\pm0.07$	$0.32^{a,b}\pm0.01$	$0.40^{a,b}\pm0.01$	$0.39^{a,b}\pm0.06$	$0.34^{a,b}\pm0.02$
16:1n-7	$1.39^{a}\pm0.04$	$1.64^{b}\pm0.01$	$1.33^{a}\pm0.03$	$1.61^{b,c}\pm0.03$	$1.52^{c}\pm0.00$	$1.35^{a}\pm0.03$
17:0	$0.33^{a}\pm0.06$	$0.29^{a}\pm0.01$	$0.29^{a}\pm0.01$	$0.31^{a}\pm0.03$	$0.30^{a}\pm0.01$	$0.32^{a}\pm0.02$
18:0	$5.22^{a,c}\pm0.30$	$4.06^{b}\pm0.14$	$5.66^{c}\pm0.06$	$5.49^{c}\pm0.18$	$4.27^{b}\pm0.10$	$4.62^{a,b}\pm0.15$
18:1n-9	$24.14^{a}\pm0.06$	$38.42^{b}\pm0.54$	$25.12^{a}\pm0.02$	$27.79^{c}\pm0.77$	$30.06^{d}\pm0.06$	$27.73^{c}\pm0.20$
18:1n-7	$2.27^{a}\pm0.08$	$3.19^{b}\pm0.15$	$2.25^{a}\pm0.23$	$2.32^{a}\pm0.01$	$2.18^{a}\pm0.27$	$2.13^{a}\pm0.01$
18:2n-6	$33.98^{a}\pm0.68$	$22.56^{b}\pm0.51$	$34.11^{a}\pm0.12$	$21.78^{b}\pm0.32$	$27.25^{d}\pm1.01$	$31.41^{c}\pm0.47$
18:3n-6	$0.92^{a,c}\pm0.06$	$0.74^{b}\pm0.07$	$1.02^{c}\pm0.03$	$0.53^{d}\pm0.00$	$0.86^{a,b,c}\pm0.02$	$0.84^{a,b}\pm0.03$
18:3n-3	$1.96^{a}\pm0.13$	$2.64^{b}\pm0.05$	$1.20^{c}\pm0.08$	$12.51^{d}\pm0.18$	$1.64^{a}\pm0.05$	$1.05^{c}\pm0.05$
20:1n-11	$0.79^{a}\pm0.19$	$0.34^{b}\pm0.01$	$0.28^{b}\pm0.00$	$0.31^{b}\pm0.02$	$1.34^{c}\pm0.15$	$0.38^{b}\pm0.02$
20:1n-9	$0.88^{a}\pm0.02$	$1.58^{b}\pm0.05$	$0.95^{a,c}\pm0.01$	$0.93^{a,c}\pm0.02$	$1.21^{d}\pm0.12$	$1.13^{c,d}\pm0.01$
20:3n-9	$1.88^{a}\pm0.09$	$1.15^{b}\pm0.06$	$2.05^{a}\pm0.00$	$1.00^{b}\pm0.06$	$1.58^{c}\pm0.03$	$1.96^{a}\pm0.03$

Table 7. (continuation) Fatty acid (FA) profile of tilapia *Oreochromis niloticus* carcass at initial phase of fingerlings submitted to diets enriched with different vegetable oils.

FA	Soybean	Canola	Sunflower	Flaxseed	Rice	Corn
21:0	$1.04^{a,c}\pm0.07$	$0.74^{b}\pm0.02$	$1.22^{c}\pm0.09$	$0.61^{b}\pm0.03$	$1.01^{a}\pm0.02$	$1.03^{c}\pm0.04$
20:4n-6	$1.61^{a}\pm0.04$	$1.19^{b,c}\pm0.08$	$1.70^{a}\pm0.02$	$0.92^{c}\pm0.04$	$1.44^{a,b}\pm0.05$	$1.54^{a}\pm0.15$
20:3n-3	$0.35^{a}\pm0.02$	$0.39^{a}\pm0.06$	$0.22^{a}\pm0.01$	$1.64^{b}\pm0.14$	$0.30^{a}\pm0.01$	$0.21^{a}\pm0.00$
20:5n-3	$0.11^{a}\pm0.01$	$0.15^{b}\pm0.05$	$0.07^{a}\pm0.01$	$0.20^{b}\pm0.02$	$0.08^{a}\pm0.01$	$0.10^{a}\pm0.01$
22:1n-11	$0.17^{a,c}\pm0.01$	$0.16^{a,c}\pm0.02$	$0.22^{a}\pm0.03$	$0.12^{b,c}\pm0.02$	$0.14^{b,c}\pm0.00$	$0.13^{b,c}\pm0.02$
22:1n-9	$0.12^{a}\pm0.00$	$0.17^{a,b}\pm0.01$	$0.11^{a}\pm0.02$	$0.22^{b}\pm0.04$	$0.11^{a}\pm0.01$	$0.13^{a}\pm0.00$
22:4n-6	$0.65^{a,c,d}\pm0.10$	$0.56^{b,c}\pm0.08$	$0.86^{d}\pm0.07$	$0.34^{b}\pm0.04$	$0.72^{a,c,d}\pm0.00$	$0.75^{a,c,d}\pm0.03$
22:5n-6	$1.41^{a,b}\pm0.22$	$1.19^{a}\pm0.24$	$1.97^{b,c}\pm0.08$	$0.56^{d}\pm0.08$	$1.69^{a,b,c}\pm0.02$	$2.01^{c}\pm0.10$
22:5n-3	$0.31^{a}\pm0.02$	$0.30^{a}\pm0.05$	$0.39^{a,c}\pm0.11$	$0.59^{b,c}\pm0.05$	$0.32^{a}\pm0.01$	$0.28^{a}\pm0.04$
22:6n-3	$1.02^{a}\pm0.22$	$1.09^{a}\pm0.24$	$1.06^{a}\pm0.02$	$1.62^{a}\pm0.32$	$1.15^{a}\pm0.09$	$1.05^{a}\pm0.11$
24:1n-9	$0.18^{a,b}\pm0.02$	$0.10^{c}\pm0.00$	ND	$0.12^{b,c}\pm0.01$	$0.24^{a}\pm0.03$	$0.10^{c}\pm0.02$
SFA	$25.59^{a}\pm0.78$	$21.95^{b}\pm0.20$	$24.77^{a}\pm0.25$	$24.50^{a}\pm0.29$	$25.79^{a}\pm0.39$	$25.37^{a}\pm0.17$
MUFA	$30.21^{a}\pm0.22$	$46.08^{b}\pm057$	$30.57^{a}\pm0.23$	$33.81^{c}\pm0.78$	$37.19^{d}\pm0.34$	$33.42^{c}\pm0.20$
PUFA	$44.19^{a}\pm0.78$	$31.97^{b}\pm0.63$	$44.66^{a}\pm0.21$	$41.70^{a,c}\pm0.52$	$37.03^{d}\pm1.01$	$41.21^{c}\pm0.52$
n-3	$3.75^{a,b}\pm0.26$	$4.59^{a}\pm0.26$	$2.94^{b}\pm0.13$	$16.57^{c}\pm0.40$	$3.49^{a,b}\pm0.10$	$2.70^{b}\pm0.13$
n-6	$38.57^{a,c}\pm0.73$	$26.24^{b}\pm0.58$	$39.67^{a}\pm0.17$	$24.13^{b}\pm0.33$	$31.95^{d}\pm1.01$	$36.55^{c}\pm0.51$
PUFA/SFA	$1.73^{a}\pm0.06$	$1.46^{b,c}\pm0.03$	$1.80^{a}\pm0.02$	$1.70^{a,b}\pm0.03$	$1.44^{c}\pm0.04$	$1.62^{a,b,c}\pm0.02$
n-6/n-3	$10.34^{a}\pm0.73$	$5.74^{b}\pm0.34$	$13.55^{c}\pm0.62$	$1.46^{d}\pm0.04$	$9.15^{a}\pm0.39$	$13.56^{c}\pm0.67$

Results expressed as percentage of total FA. Values are mean ± standard deviation of five samples and triplicate analyses. SFA = total saturated FA; MUFA = total monounsaturated FA; PUFA = total polyunsaturated FA; n-3 = total omega-3 FA; n-6 = total omega-6 FA; ND = not detected. Averages followed by different letters in same line are significantly different ($P < 0.05$) by Tukey's test.

In all treatments, the moisture values were higher than those found for tilapia (*Oreochromis* sp.) by Izquierdo *et al.* (2000), 72.36%, and similar to those observed by Puwastien *et al.* (1999), 78.1%, Justi *et al.* (2003), 78.75%, and Visentainer *et al.* (2005), 77.4%, for Nile tilapia (*Oreochromis niloticus*). They also reported similar percentages for protein (19.8%) content. On the other hand, Izquierdo *et al.* (2000) found a higher protein content (23.34%), but quite similar ash and lipid contents, 1.94% and 2.26%, respectively. Justi *et al.* (2003) found a similar protein value (18.2%), but higher ash and lipid values, 1.91 and 1.95%, respectively. The lipid percentages found in this study were also in agreement with the percentage of 1.8% observed by Puwastien *et al.* (1999), who found a lower ash content (1.0%).

The results obtained for soybean, canola, sunflower, corn, and rice oils are in agreement with those found by Andrade *et al.* (1994). Based on these results, it can be stated that the flaxseed oil is the most suitable tilapia diet complement, since it has a high PUFA content and the highest percentage of n-3 fatty acids.

The observed values of docosahexaenoic acid (DHA, 22:6 n-3) were higher than those of eicosapentaenoic acid (EPA, 20:5 n-3), which is in agreement with the values reported for most freshwater fish muscles (Ahlgren *et al.*, 1994). Fish treated with flaxseed oil-enriched feed presented the highest values of DHA and total n-3 PUFA, being these values higher than those reported by Andrade *et al.* (1995) for tilapia (*Oreochromis niloticus*), 0.94% for DHA and 4.81% for n-3 PUFA, and lower than those found by Izquierdo *et al.* (2000), 5.0% for DHA in tilapia (*Oreochromis* sp.).

The Department of Health of England (HMSO, 1994) recommends a minimum PUFA/SFA ratio of 0.45, and a maximum n-6/n-3 of 4.0. Table 6 shows that the fingerlings of all treatments met the PUFA/SFA ratio and a better value was found for n-6/n3 ratio for fingerlings fed the flaxseed oil-enriched diet.

In the examination of the fatty acids composition of the samples investigated in this work, it is possible to verify that none of the vegetable oils used affected the performance of the fingerlings and that they can be utilized in their diets. However, the nutritional quality of fingerlings depends on the type of oil and its content in feeds, showing that feeds have a great influence on the fatty acid profile of tilapia carcass. Based on the results obtained, the use of flaxseed oil in the diet of Nile tilapia fingerlings, due to their nutritional value it is recommended.

Conclusion

In the examination of the fatty acids composition of the samples investigated in this work, it is possible to verify that none of the vegetable oils used affected the performance of the fingerlings and that they can be utilized in their diets. However, the nutritional quality of fingerlings depends on the type of oil and its content in feeds, showing that feeds have a great influence on the fatty acid profile of tilapia carcass. Based on the results obtained, the use of flaxseed oil in the diet of Nile tilapia fingerlings, due to their nutritional value it is recommended.

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