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RESEARCH PAPER

Fatty Acid Composition of Fillets of African Catfish, *Clarias gariepinus* Fed with Various Oil-Based Diets

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Abstract

This study evaluated effects of diets containing different vegetable oil resources on growth performances, body compositions and fatty acid profile of *Clarias gariepinus.* The oils were incorporated at 7% level of the diet. Fingerlings were randomly stocked at 20 fish per floating net-hapa ($1m^3$) and fed the experimental diets for 12 weeks. Fatty acid methyl esters and proximate compositions were determined. Growth performances revealed that fish fed palm oil-based diets yielded best. Fatty acids profile revealed that lauric, myristic and palmitic acids were the main saturated fatty acids while oleic acid was the main monounsaturated fatty acids. High levels of docosahexaenoic acid (DHA) (22:6n-3) and arachidonic acid (ARA) (20:4n-6) were observed in muscle lipid of fish fed with sunflower oil diet. The main contributor of saturated fatty acids was lauric with the highest amount (82.57%) reflected in fish fed coconut oil diet. The highest ($P<0.05$) monounsaturated fatty acids (73.55%) was in fish fed olive oil diet. Proximate analysis revealed catfish belongs to high-protein (15 - 20%) and high-oil (>5%) category. The ω-3/ω-6 ratios obtained in muscle fatty acids of catfish fed olive, sunflower and sesame-oil diets were within the recommended daily intake of EPA and DHA for normal human health.

Introduction

Aquaculture is an integral component of the overall agricultural production system in Nigeria. The country with hundreds of rivers and ponds is notable for being a fish-loving nation where fish plays an important role in the diets, constituting the main and often irreplaceable animal protein source in both urban and rural households (Otubusin, 2011). Fish oil, the traditional lipid source in aquaculture plays an important role in commercial diets of fish as concentrated source of energy and essential fatty acids for growth, development, proper functioning of many physiological processes and maintenance of membrane fluidity and permeability (Pie, Xie, Lei, Zhu, & Yang, 2004). They are also an essential component of steroids and phospholipids used as precursors in the synthesis of certain vitamins and hormones and vehicles for absorption of fat–soluble vitamins and exhibit many hormonal activities (Ng, Wang, & Yuen, 2008).

Consumers would usually desire to know if there are nutritional differences in various fish species from different sources. This can only be answered through proximate analysis of body composition of various fish species. Karapanagiotidis, Bell, Little, and Yakupitiyage (2007) reported that some fishes are high in omega-3 and omega-6 PUFA depending on some external (environment, culture method and climatic effects) and internal (genetic make-up, feeding regime, life cycle stage) factors. The essential fatty acids: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are of interest in human diets because they

reduce the risk of human cardiovascular diseases (Leaf & Kang, 1996). A daily intake of 500mg EPA and DHA has been recommended for the primary prevention of coronary heart disease (ISSFAL, 2004). In addition, fatty acid composition data are needed by food scientists and nutritionists to aid them in dietary formulation, processing and product development.

Test panels have also indicated that consumers more likely to prefer the taste of fish fed mixtures of plant and fish oil rather then fed only with fish oil (Ochang, 2011). Hence, fish farmers have welcomed the use of plant ingredients in fish feed hoping it can help stabilize feed costs. The available evidence suggests that alternatives are being developed at a rapid rate and are increasingly being used to replace and supplement fish meal and oil in aqua feeds. All this has led FAO, in its 2012 Report on the State of World Fisheries and Aquaculture (FAO, 2013) to conclude that, as the production of fishmeal and fish oil is expected to remain stable over the next decade, the proportion of fish oil used by the animal production sector is expected to fall and the use of vegetable-based protein and oil to increase. The overall picture is therefore a gradual substitution of fish oil with suitable alternatives as an increasing eco-efficiency of aquaculture which is likely to result in reduced pressure on industrial fish stocks. This has necessitated the present study.

Materials and Methods

Experimental Design

The experimental setup composed of an outdoor concrete tank (8m x 5m x 1.65m) situated at the Vika Farms Limited, Mbak Etoi, Uyo, Nigeria. The farm is located at geographical coordinates of Latitude: 5º03'0''N and Longitude 7º56'0''E. This tank was equipped with both inlet and outlet facilities and a 5,000 liter capacity overhead tank served as a water reservoir. The experimental design was made out of a module consisting of 8.5m x 6.0m bamboo raft with eighteen 1.5m x 1.5m apartments fittable with eighteen 1m x 1m x 1m hapas constructed and placed to fit on the concrete tank as described by Otubusin (2000).

Diet Preparation and Fish Rearing

Six isonitrogenous diets (41.00% protein) were prepared (Table 1). In diet 1 (control), fish oil served as the lipid source. In diets 2 to 6, coconut, olive, crude palm, sunflower and sesame seed oils were used as total replacement for fish oil respectively. The various oils were incorporated at 7% of the diet. Ingredients were carefully weighed, mixed, made into pellets using 2mm meat mincer, air-dried and labeled separately according to diets. Catfish (4.5±0.10g) were stocked at 20/m^3. Fish were fed in triplicate groups at 5% body weight for 12 weeks.

Determination of Growth Performances

The following growth performance indices were estimated using standard formulae (Jamabo and Alfred-Ockiya, 2008) thus:

Mean weight gain (MWG) (g) = Final weight (g) – Initial weight (g).

Average daily growth (ADG) = MWG (g)/length of feeding trial (t) (days).

Specific Growth Rate (SGR, %/day) = $100(\ln W_2 - \ln W_1)/T_2-T_1$

Where: W_2 = Weight at time T_2; W_1 = Weight at time T_1

Feed conversion Ratio (FCR) = Total dry feed fed (g)/MWG (g).

Protein efficiency Ratio (PER) =MWG (g)/total protein fed (g).

Survival rate (SR) = 100(Number at end of feeding trial/Number at start of feeding trial).

Table 1. Composition (g/kg) of experimental diets containing different lipid sources

Ingredients	Control	Coconut	Olive	Palm	Sunflower	Sesame
FM	186.00	186.00	186.00	186.00	186.00	186.00
SBM	186.00	186.00	186.00	186.00	186.00	186.00
CFL	182.00	182.00	182.00	182.00	182.00	182.00
GNC	375.00	375.00	375.00	375.00	375.00	375.00
Lysine	0.300	0.300	0.300	0.300	0.300	0.300
Methionine	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
Premix*	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
Fish oil	70.00	-	-	-	-	
Coconut oil	-	70.00	-	-	-	-
Olive oil	-		70.00	-	-	-
Palm oil	-	-	-	70.00		-
Sunflower oil	-	-	-	-	70.00	
Sesame oil	-	-	-	-	-	70.00

* Fish Premix (per kg of diet): Vitamin A: 10,000,000 I.U.D; D3: 2,000,000 I.U.D; E: 23,000mg; K3: 2,000mg; B1: 3000mg; B2: 6,000mg; niacin: 50,000mg; calcium pathonate: 10,000mg; B6: 5000mg; B12: 25.0mg; folic acid: 1,000mg; biotin: 50.0mg; choline chloride: 400,000mg; manganese: 120,000mg; iron: 100,000mg; copper: 8,500mg; iodine: 1,500mg; cobalt: 300mg; selenium: 120mg; antioxidant: 120,000mg.

Proximate Analysis of Fish Carcass

Proximate analysis of fish carcass was done according to standard AOAC method (AOAC, 2004). Moisture content was done by oven-drying to a constant weight; total ash by muffle furnace combustion; crude fibre by trichloroacetic acid method; lipid content by soxhlet extraction method; protein by micro – kjeldahl method, carbohydrate was calculated as difference obtained after subtracting moisture, total organic nitrogen (protein), ether extract, ash and fibre from 100%. Caloric value was estimated based on physiological fuel values (0.2364 KJ/g for protein; 0.3954 KJ/g for lipid and 0.1715 KJ/g for carbohydrate) as described by Henken, Machiels, Dekker, and Hogendoorn (1986).

Lipid Extraction and Fatty Acid Analysis

The extraction of total lipids and preparation of fatty acid methyl esters were performed according to Musa (2009). Fatty acid analysis was carried out on a gas chromatograph (Hewlett Parkard: 6890) fitted with an automatic sampler (Model: AS 2000B) and flame ionization detector. The conditions used were: Omega wax fused silica capillary column BPX-70 (60m x 0.32mm i.d., 0.25µm film thickness) (SGE; Melbourne, Australia). The starting temperature was 108^{o}C; this was later raised to 115^{o}C at a rate of 8^{o}C/min and held for 10 minutes. This temperature was finally raised to 240^{o}C at a rate of 8^{o}C/min and held for another 10 minutes. The sample size was 1µl and flashed through helium as the carrier gas at a rate of 1.6 ml/min with inlet pressure of 12 psi. Fatty acids methyl esters were identified in comparison to an external standard (SupelcoTM 37 component FAME Mix).

Statistical Analysis

Data were entered using Microsoft Excel version 2013. Analysis of variance (ANOVA) was used to determine the variation among the treatments while Duncan multiple range test was used to separate the means. All analyses were performed at 95% confidence interval. Statistical Analysis were done using Statistical Package for Social Sciences (SPSS) software (Version 22.0 for Windows; SPSS Inc., Chicago, IL, USA).

Results

The fatty acid profiles of *C. gariepinus* are shown in Table 2. The sequence of the fatty acids was ordered according to their chromatographic retention times and the values were given as mole percent of the total fatty acid methyl esters. Dietary lipid sources have significantly influenced ($P<0.05$) the fatty acid composition of fish. Lauric (12:0), myristic (14:0), and palmitic (16:0) acids were the main saturated fatty acids while oleic acid (18:1) was the main monounsaturated fatty acids. High levels of docosahexaenoic acid (22:6n-3, DHA) and arachidonic acid (20:4n-6, ARA) were observed in muscle lipid of fish fed sunflower oil diet. The main contributor of saturated fatty acids was lauric (12:0) with the highest value (82.57%) reflected in fish fed coconut oil diet. The amount of monounsaturated fatty acids was highest (73.55%) in fish fed with the olive oil diet. The ratio of n-3 fatty acids to n-6 fatty acids was highest in fish fed with the sesame oil diet and lowest in those fed with the coconut oil diet.

The crude protein content of diets varied slightly (Table 3). Fish fed with palm oil diet had the highest protein content which was statistically indifferent ($P>0.05$) to those fed with control diet while the group fed with coconut diet recorded the least protein and the highest lipid content. Ash contents were generally lower in all treatments when compared with the initial level with no statistical difference ($P<0.05$) among tested diets. Results of bivariate analysis showed high positive correlation between moisture content and crude protein ($r = 0.916$), gross energy ($r = 0.904$) and crude lipid ($r = 0.900$). This indicated that whole body compositions increased linearly and were influenced by lipid contents in diets.

Results of growth performances (Table 4) revealed that the highest growth (mean final weight) (236.77g), mean weight gain (232.06g), average daily growth (2.76g), and, specific growth rate (4.66%/day) were obtained in fish fed with palm oil-based diet. When compared with the control group, fish fed with alternative oil diets yielded quite acceptable growth responses. The high survival rates in all tested diets signified that there was neither palatability problem nor feed intake depression. The fish on all experimental diets showed satisfactory diet acceptance at 7% oil inclusion level.

Discussion

The results obtained in this study yielded quite acceptable growth responses in fish fed different vegetable oil diets when compared to those fed with the control diet. Improved feed conversion and protein efficiency ratios were observed in fish fed palm oil diet. This was also reported by Babalola and Adebayo (2007) in catfish. The study also agreed with growth improvement earlier reported by Pie, Xie, Lei, Zhu, & Yang (2004) and confirmed the suitability of this oil in fish feed formulation since Lim, Leamaster, & Brock (1993) showed that crude palm oil is the richest natural source of ß-carotene, a precursor of vitamin A, which is useful in providing energy density to the diet leading to improved fish growth. In addition, some of the minor components of palm oil especially carotenoids, phosphatides, sterols, tocopherols, tocotrienols and a rich source of vitamin E are of nutritional importance. However, fish treated with all experimental diets

Table 2. Muscle fatty acid (% of total fatty acid) of catfish fed diets containing different lipid sources

Indices	Control	Coconut oil	Olive oil	Palm oil	Sunflower oil	Sesame oil
8:0	-	1.34±0.02	-	-	-	-
10:0	-	0.49±0.12	0.67±0.01	-	0.36±0.03	-
10:2	-	0.27±0.07	2.26±0.09	-	0.34±0.04	-
12:0	2.36±0.02^{c}	49.40±0.2^{d}	0.03±0.00	0.79±0.04^{b}	0.05±0.00	0.50±0.01^{b}
14:0	4.17±0.06^{d}	12.40±0.20^{e}	2.69±0.25^{c}	2.23±0.01^{c}	0.51±0.10^{a}	0.26±0.03^{a}
14:n-5	1.39±0.08^{c}	2.66±0.19^{d}	1.29±0.02^{c}	3.15±.01^{c}	0.53±0.00^{a}	0.82±0.03^{b}
15:0	0.31±0.02^{b}	0.28±0.06^{b}	1.32±0.03^{d}	0.03±0.00^{a}	0.38±0.00^{d}	0.72±0.02^{c}
16:0	8.03±0.01^{d}	6.29±0.04^{c}	3.39±0.03^{a}	23.40±0.02^{e}	6.40±0.02^{c}	5.40±0.06^{b}
16:n-7	0.73±0.06^{b}	3.66±0.01^{c}	0.40±0.00^{a}	7.47±0.23^{e}	3.26±0.03^{c}	4.27±0.04^{d}
16:n-9	0.04±0.00	0.02±0.00	0.03±0.00	0.04±0.00	0.02±0.00	0.31±0.00
17:0	1.41±0.15	0.32±0.01	0.20±0.00	0.06±0.02	0.79±0.03	0.26±0.03
17:1	0.46±0.08	0.03±0.00	0.03±0.00	0.02±0.00	0.74±0.05	0.08±0.01
18:0	8.28±0.23^{d}	4.74±0.38^{a}	4.24±0.04^{a}	6.31±0.14^{c}	5.56±0.03^{b}	6.40±0.15^{c}
18:n-7	10.33±0.1^{b}	4.35±0.01^{a}	42.29±0.05^{f}	30.41±0.17^{e}	13.32±0.05^{c}	25.36±0.03^{d}
18:n-9	6.35±0.03^{b}	4.73±0.01^{a}	31.24±0.03^{f}	12.33±0.06^{d}	10.36±0.03^{c}	17.21±0.01^{e}
18:2n-6	27.61±0.1^{e}	4.29±0.07^{a}	4.29±0.01^{b}	6.31±0.11^{c}	29.48±0.12^{f}	18.41±0.01^{d}
18:3n-3	24.44±0.3^{e}	2.82±0.01^{a}	4.72±0.01^{b}	1.82±0.01^{a}	26.31±0.07^{d}	16.04±0.08^{c}
18:3n-6	0.72±0.05^{d}	0.41±0.01^{b}	0.04±0.00^{a}	0.40±0.01^{b}	0.61±0.10^{c}	0.89±0.04^{e}
18:4n-6	0.63±0.01^{c}	0.26±0.03^{b}	0.01±0.00^{a}	0.03±0.00^{a}	0.03±0.00^{a}	0.03±0.00
20:0	0.38±0.08^{b}	0.03±0.00^{b}	0.03±0.00^{a}	0.03±0.00^{a}	0.02±0.00^{a}	0.02±0.00^{a}
20:n-9	0.57±0.08^{c}	0.51±0.01^{c}	0.11±0.01^{b}	0.05±0.00^{a}	0.25v0.04^{b}	0.31±0.20^{b}
20:2n-6	0.61±0.01^{d}	0.12±0.00^{b}	0.03±0.00	0.04±0.00^{a}	0.37±0.06^{c}	0.32±0.01^{c}
20:3n-3	0.37±0.13^{c}	0.03±0.00^{a}	0.17±0.02^{b}	0.05±0.00^{a}	0.05±0.00^{a}	0.64±0.20^{d}
20:3n-6	0.76±0.07^{c}	0.02±0.00^{a}	0.03±0.00^{a}	0.02±0.00^{a}	0.05±0.00^{a}	0.56±0.03^{b}
20:4n-3	0.34±0.02^{c}	0.21±0.00^{b}	0.03v0.00^{a}	0.02±0.00^{a}	0.06±0.00^{a}	0.71±0.01^{d}
20:4n-6	0.67±0.00^{d}	0.13±0.00^{b}	0.15±0.01^{b}	0.25±0.02^{c}	0.01±0.00	0.37±0.03^{a}
20:5n-3	1.18±0.09^{c}	0.04±0.00^{a}	0.26±0.01^{b}	0.37±0.02^{b}	0.05±0.00^{a}	0.02±0.00^{a}
22:0	0.32±0.01^{c}	0.05±0.00^{a}	0.07±0.00^{a}	0.05±0.00^{a}	0.21±0.01^{b}	0.02±0.00^{a}
22:n-9	1.58±0.16^{c}	0.06±0.00^{a}	0.03±0.00^{a}	0.67±0.01^{b}	0.06±0.00^{a}	0.03±0.00^{a}
22:4n-6	0.61±0.01^{c}	0.03±0.00^{a}	0.02±0.00^{a}	0.15±0.03^{b}	0.06±0.00^{a}	0.86±0.01^{d}
22:5n-3	0.06±0.00	0.04±0.00	0.02±0.00	0.08±0.01	0.03±0.00	0.02±0.00
22:5n-6	0.49±0.02	0.03±0.00	0.02±0.00	0.18±0.00	0.04±0.01	0.06±0.00
22:6n-3	0.97±0.08	0.04±0.00	0.03±0.00	0.05±0.00	0.07±0.02	0.08±0.01
24:0	0.30±0.00	0.03±0.00	0.03±0.00	0.01±0.00	0.04±0.00	0.04±0.00
24:1	0.40±0.00	0.04±0.00	0.04±0.00	0.03±0.00	0.03±0.00	0.01±0.00
∑ SAT	26.52±0.3^{c}	82.57±0.01^{e}	17.05±0.3^{a}	46.73±0.26^{d}	20.95±0.25^{b}	19.85±0.4^{b}
∑ MUFA	18.68±0.1^{b}	9.08±0.04^{a}	73.55±0.08^{e}	42.74±0.15^{d}	23.68±0.05^{c}	42.57±0.04^{d}
∑ PUFA	52.05±0.0^{d}	4.11±0.08^{a}	9.10±0.01^{b}	8.13±0.10^{b}	55.79±0.14^{e}	11.06±0.07^{c}
∑ n-3	38.99±0.3^{f}	4.94±0.17^{b}	7.23±0.02^{c}	2.42±0.06^{a}	35.51±0.03^{e}	12.03±0.48^{d}
∑ n-6	32.47±0.0^{d}	1.50±0.11^{c}	4.57±0.01^{b}	7.34±0.04^{c}	38.83±0.38^{e}	6.67±0.02^{c}
∑ n-3/n-6	1:1.2±0.0^{b}	1:0.05±0.00	1:1.59±0.0^{c}	1:0.33±0.0^{a}	1:0.91±0.0^{b}	1:1.80±0.1^{c}

Data are mean ± standard error; means with different superscript within a row are significantly different ($p < 0.05$).

Table 3. Proximate carcass composition (% wet weight) and gross energy (kJ/g) of catfish fed diets containing different lipid sources

Indices	Initial	Control	Coconut	Olive	Palm oil	Sunflower	Sesame
Moisture	75.88^{f}	70.74±0.20^{a}	73.34±0.12^{e}	72.73±0.10^{d}	71.45±0.32^{b}	72.15±0.11^{c}	72.20±0.07^{c}
Ash	4.24^{c}	3.42±0.18^{ab}	3.17±0.07^{a}	3.16±0.08^{a}	3.22±0.15^{a}	3.62±0.15^{b}	3.13±0.06^{a}
Protein	15.35^{a}	18.96±0.19^{d}	16.19±0.07^{b}	17.18±0.05^{c}	18.66±0.13^{d}	17.18±0.11^{c}	17.21±0.09^{c}
Lipid	3.05^{a}	5.43±0.05^{b}	6.80±0.23^{d}	6.15±0.07^{c}	6.00±0.01^{c}	6.07±0.04^{c}	6.14±0.08^{c}
Fibre	1.21^{c}	0.51±0.22^{b}	0.06±0.61^{a}	0.05±0.03^{a}	0.14±0.09^{a}	0.25±0.04^{ab}	0.37±0.13^{b}
NFE	0.27^{a}	0.94±0.07^{b}	0.45±0.20^{ab}	0.73±0.23^{ab}	0.53±0.23^{ab}	0.73±0.14^{ab}	0.87±0.13^{b}
Energy	4.88^{a}	6.79±0.05^{c}	6.59±0.08^{b}	6.63±0.03^{b}	6.87±0.07^{c}	6.58±0.01^{b}	6.64±0.04^{b}

Data are mean ± standard error; means with different superscript within a row are significantly different ($p < 0.05$).

Table 4. Growth performance of catfish fed diets containing different lipid sources

Indices	Control	Coconut	Olive	Palm	Sunflower	Sesame
MIW(g)	4.71±0.01	4.71±0.01^{b}	4.71±0.01	4.71±0.01	4.71±0.01	4.70±0.00
MFW(g)	213.2±1.95^{d}	188.0±1.37^{b}	209.2±1.84^{cd}	236.8±3.7^{e}	203.3±3.0^{c}	171.73±1.25^{a}
MWG(g)	208.5±1.15^{d}	183.3±1.37^{b}	204.5±1.85^{cd}	232.1±3.7^{e}	198.6±3.0^{c}	167.03±1.25^{a}
ADG(g/day)	2.49±0.01^{d}	2.18±0.01^{b}	2.14±0.02^{cd}	2.77±0.04^{e}	2.36±0.03^{c}	1.99±0.02^{a}
SGR(%/day)	4.54±0.01^{d}	4.39±0.01^{b}	4.51±0.01^{cd}	4.66±0.02^{e}	4.5±0.02^{c}	4.28±0.01^{a}
FCR	0.27±0.00^{b}	0.25±0.01^{a}	0.27±0.01^{b}	0.27±0.00^{b}	0.26±0.01^{ab}	0.26±0.00^{ab}
PER	8.94±0.12^{a}	9.68±0.18^{c}	9.05±0.10^{ab}	8.85±0.04^{a}	9.09±0.25^{ab}	9.44±0.02b^{c}
SR (%)	98.33±1.67	98.33±0.00	98.33±1.67	100.0±0.00	98.33±1.67	100.0±0.00

Data are mean ± standard error; means with different superscript within a row are significantly different ($p < 0.05$). Where; MIW=mean initial weight; MFW=mean final weight; ADG=average daily growth; SGR=specific growth rate; FCR=food conversion ratio; PER=protein efficiency ratio; SR=survival rates

showed satisfactory diet acceptance at 7% oil inclusion levels. This indicated that there was neither palatability problem nor feed intake depression.

Detailed information about lipid components and their fatty acid constituents are needed to understand how to diminish oxidative or hydrolytic factors which affect the quality of fish. Fatty acids profile analysis also provides information about the essential fatty acids requirements of fish which would aid the compounding of adequate protein-to-fat ratio feed that would balance energy requirements with caloric intake. Ackman (2000) stated that only 14 fatty acids are really needed to describe the fatty acids of fish. This study recorded about 24 fatty acids of the total lipid, indicating that the results presented in this study are valid. Other study by Ackman, Mcleod, Rakshit, and Misra (2002) opined that dominant fatty acids in lipids of all fishes were myristic (14:0), palmitic (16:0), stearic (18:0), palmitoleic (16:n-7), oleic (18:n-9), linoleic (18:2n-6), linolenic (18:3n-3), arachidonic (20:4n-6), eicosapentaenoic (20:5n-3) and docosahexaenoic (22:6n-3) acids. Results of present study corroborated with the above findings. High dietary intake of saturated fatty acids is a risk factor for development of obesity and cardiovascular disease (Gillian *et al.,* 2008). Palm oil contains a high proportion of palmitic acid as well as considerable quantities of oleic and linoleic acids which gives it a higher unsaturated fatty acid content than coconut oil (Edem, 2002). The high proportion of palmitic acid observed in fish fed palm oil diet was also reported by Abdulkarim, Myat, and Ghazali (2010). High content of MUFA especially oleic acid (18:1) is associated with a low incidence of coronary heart disease because it decreases total cholesterol by 10% and low-density lipoprotein cholesterol (Dennys *et al.,* 2006).

Dietary intake of certain unsaturated fatty acids, in particular conjugated linoleic and fat-soluble antioxidants (e.g. α-tocopherol, carotenoids) has been linked to potential health benefits (Gillian *et al.,* 2008). The presence of lauric acid in coconut oil was in line with Gopala, Aguaray, Ajit, Prasanth, and Preeti (2010) who reported that coconut oil is a major source of lauric acid. Enig (1995) earlier reported that lauric acid is a rare medium-chain fatty acid found in mother's milk that supports healthy metabolism and is now being studied for its anti-fungal, anti-viral, and anti-bacterial health-protecting properties. Coconut oil has a unique nutritional value as an important physiologically functional feed additive. The health and nutritional benefits that can be derived from consuming coconut oil have been recognized in many parts of the world for centuries. A review of the diet and/or heart disease literature relevant to coconut oil clearly indicated that coconut oil is at worst neutral with respect to atherogenicity of fats and oils and, in fact, is likely to be beneficial oil for prevention and treatment of some heart diseases. Additionally, coconut oil provides a source of antimicrobial lipid for individuals with compromised immune systems and is a non-promoting fat with respect to chemical carcinogenesis.

The principal acids in the polyunsaturated group were linoleic, eicosapentaenoic and docosahexaenoic. The concentrations of DHA and EPA were similar to those of other reports (Ahlgren, Blomquist, Boberg, & Gustafsson, 1994; Clement & Lovell, 1994) where freshwater fishes indicated the dominance of these fatty acids in the tissue lipids of fish. Sargent (1996) noted that n-3 PUFA, principally DHA, has a role in maintaining the structure and functional integrity membranes. Moreover, DHA is considered a desirable property in fish for human nutrition and health. The significance of this study was that the values of n-3 to n-6 ratios obtained in muscle fatty acids of catfish fed olive, sunflower and sesame-oil based diets were within the recommended daily intake (1:1 to 1:1.5) of EPA and DHA for normal human health (Osman, Zurria, & Law, 2000). The results therefore suggested that the efficiency of elongation and desaturation of C18 fatty acids depended on the dietary lipid source and catfish had the capacity to transform linoleic and linolenic acids to ARA and DHA respectively. Therefore, *C. gariepinus* is a good source of high-protein, high-lipid and high n-3 polyunsaturated fatty acids, particularly EPA and DHA.

Moisture content of fish muscle was within previously reported range in other fishes (Gallagher, Harrell, & Rulifson, 1991). The observed range of ash

content indicated that the African catfish is a good source of minerals such as calcium, potassium, zinc, iron and magnesium. The fish in this study could considered to be included in high-protein (15 - 20%) high-oil (>5%) category since fishes with lipid content below 5% are considered lean (Ackman, 1989). Hence, *Clarias gariepinus* fed with different oil diets under the condition of this study was not a lean fish. The concentration of the protein content was within the range previously reported for freshwater fish from both temperate (Henderson & Tocher, 1987) and tropical (Andrade, Rubira, Matsushita, & Souza, 1995) regions. The lipid content also fell within the range previously detected in fish by Mendez, Gozalez, Innocent, Giudice, and Grompone (1996).

Conclusions

This study has revealed that fish fed with different vegetable oil diets resulted in positive growth responses. It also revealed that all the experimental oils were unique in their fatty acid composition and that the composition of the different experimental oils supports human health. However, olive, sunflower and sesame oils were all good sources of essential fatty acids required in human diets and could replace fish oil in fish feed production.

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