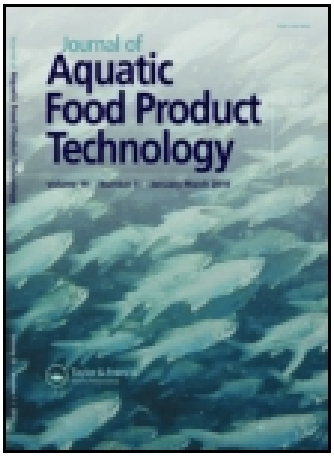

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Fatty Acid Composition of Muscle, Liver, and Adipose Tissue of Freshwater Fish from Lake Victoria, Uganda

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Fish oils may differ in fatty acid (FA) composition depending on diet. Oils extracted from muscle, liver, and adipose tissue of Nile perch (Lates niloticus), Nile tilapia (Oreochromis niloticus), silver fish (Rastrineobola argentea), lungfish (Protopterus aethiopicus), Victoria squeaker (Synodontis victoriae), and two catfishes (Clarias gariepinus and Bagrus docmac) from Lake Victoria, a tropical freshwater lake, were evaluated for FA composition. Oil contents of muscles, livers, and adipose tissues were in the range of 3.16 to 13.8%, 3.62 to 53.4%, and 28.8 to 42.4%, respectively. Omega-3 polyunsaturated FA, particularly alpha-linolenic (ALA), eicosapentaenoic (EPA), docosapentaenoic (DPA), and docosahexaenoic (DHA) acids, were found to be in substantial amounts in oils from all seven fish species. Ratios of polyunsaturated FA to saturated FA (0.79 to 1.18) were in the range considered adequate for normal health. Overall, the results show that the fish species studied are a rich source of omega-3 polyunsaturated FA.

Keywords Freshwater fish, fatty acid composition, omega-3 PUFA, Lake Victoria

Introduction

Fatty fish from temperate environments are considered to be the major natural source of omega-3 polyunsaturated fatty acids (PUFA; Henderson & Tocher, 1987). Tropical freshwater fish have also been found to contain substantial amounts of omega-3 PUFA (Zenebe et al., 1998; Kwetegyeka et al., 2006; Ogwok et al., 2009). Fish livers (Saify et al., 2003), belly flaps (Ogwok et al., 2008), and muscles (Polvi and Ackman, 1992) provide the major fat deposits including substantial amounts of omega-3 PUFA. Fat content and fatty acid profile of fish lipids have been demonstrated to vary with species (Aggelousis & Lazos, 1991; Kwetegyeka et al., 2006) and diet (Moffat and McGill, 1993; Aggelousis and Lazos, 1991).

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Omega-3 PUFA, especially docosahexaenoic acid (DHA; 22:6, n-3) and eicosapentaenoic acid (EPA; 20:5, n-3), provide clinical benefits when consumed in adequate amounts (Harper and Jacobson, 2001). Long-chain omega-3 PUFA primarily reduce blood clotting activity of platelets and the formation of plaques (Leaf and Weber, 1988). Omega-3 PUFA, in addition, influence blood lipid profiles by lowering blood triglycerides and blood cholesterols (Harris, 1997). As a result, adequate consumption of omega-3 PUFA prevents cardiac arrhythmias and sudden death caused by heart attacks (Leaf and Weber, 1988). The cholesterol-lowering effect of linoleic acid (LA), a major omega-6 PUFA, is also well-recognized from human clinical trials (Mensink and Katan, 1992; Harris et al., 2009). Prospective cohort studies suggest a modest benefit of omega-6 PUFA intake on coronary heart disease (CHD; Dolecek, 1992; Harris et al., 2009). A low amount of omega-6 PUFA is generally recommended in human diets given its potential to increase blood platelet activity (Zock and Katan, 1998). Both omega-3 and omega-6 PUFA are, however, required for good health (Harris et al., 2009). Information on long-chain PUFA of foodstuffs is therefore required for dietary formulations and product development for nutrient deprived individuals.

Fish livers and belly flaps are by-products of fish processing. In Uganda, approximately half of the total fish production, estimated between 220,000 and 250,000 tons per annum, is used in a semi-processed form (Yongo et al., 2005). Data on lipid content and fatty acid composition of most fish species from Lake Victoria is limited. Therefore, compositional data is necessary to establish levels of omega-3 PUFA in freshwater fish from Lake Victoria. Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus*), silver fish (*Rastrineobola argentea*), catfish (*Bagrus docmac* and *Clarias gariepinus*), lungfish (*Protopterus*), and Victoria squeaker (*Synodontis victoria*) are presently considered to be the major fish species of Lake Victoria (Yongo et al., 2005). Fish oils from their muscles, livers, and adipose tissues were analyzed to establish their content of omega-3 and omega-6 PUFA.

Materials and Methods

Sampling

Fish from two locations (Kasenyi and Ggaba) on Lake Victoria (Uganda) were collected in February 2008. Twenty (20) samples each of Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus*), catfish A (*Bagrus docmac*) and B (*Clarias gariepinus*), lungfish (*Protopterus*), Victoria squeaker (*Synodontis victoria*), and 1 kg of silver fish (*Rastrineobola argentea*) were obtained. Samples for each species were placed in separate black plastic boxes with ice layers between layers of fish and then covered using aluminium foil. Fish muscles were obtained by filleting. Adipose tissues and livers were obtained immediately after filleting. Fish oils were extracted immediately as described below from the muscles, livers, and adipose tissues. Data for silver fish was derived from analysis of the whole fish body; the liver and adipose tissue could not be separated manually because of the very small fish size (40 g).

Extraction of Oils

Fish muscles, livers, and adipose tissues (350 g) were separately homogenized at ambient temperature using a Waring Blender 800E (Waring, New Hartford, CT, USA) run at 1000 rpm for 12 min. A whole silver fish was homogenized. Oil was extracted according to the

procedure described by Turon et al. (2005). Crude fish oil was extracted by incubating the homogenate at 35°C for 1 h. Denatured materials were separated from oils by decanting, and the oil was dried by mixing with anhydrous sodium sulphate (20 g/100 g of oil). Dried oils were centrifuged, decanted, weighed, and expressed as a percentage of the homogenate on a wet weight basis. The crude oils were stored at −20°C in amber vials. Fatty acid composition was determined within a week.

Determination of Fatty Acid Composition

Fatty acid methyl esters (FAME) were prepared by acid-catalyzed methanolysis as described by Grahl-Nielsen and Barnung (1985). The acidified solution of anhydrous methanol (2M, 1 mL) was added to the oils (20 mg) contained in thick-walled glass tubes (15 mL). The tubes were tightly capped with Teflon lined screw caps, placed in an oven at 90°C, and left for 2 h for esterification. Subsequently, FAME was extracted from the mixture by solvent extraction using a water-hexane (1:2) solvent system and centrifuged (Thermo Centre CL2, Needham Heights, MA, USA) at 355 × *g* for 10 min. The FAME was obtained from the hexane layer by siphoning. Extraction was continued by adding hexane (1 mL) to the residual mixture.

Oils were evaluated for fatty acid profile using a gas chromatograph (GC; HP 5890, Hewlett Packard, Palo Alto, CA, USA) coupled with a mass spectrometer (MS). The MS was equipped with an electron impact ionizer (1600 Em volts) and a quadruple effect mass analyzer operating in total ion mode (50 to 600 amu). Helium was used as the carrier gas at a rate of 23.4 mL/min. The injector and detector were each maintained at 250°C. Temperature was programed from 90 to 210°C; it was raised at a rate of 30°C/min, held isothermal for 4 min, and then raised to 223°C at 1°C/min. One (1) μL of FAME in hexane was injected into the GC-MS instrument (split mode/ratio, 1:1). A fused silica capillary column (30 m × 0.53 mm) coated with 8.12% diphenylpolysiloxane (Chrompack, Middleburg, The Netherlands) was used as the stationary phase. A quantitative assay of fatty acids was achieved by comparison of analyte GC signals to corresponding signals of a standard mixture of FAME (GLC-490) from Nu-Chek-Prep (Elysian, MN, USA). Quantification was performed using TurboChrom software (Perkin-Elmer, Norwalk, CT, USA). The amounts of fatty acids in the oils were expressed as a percentage of the total fatty acid quantified.

Statistical Analysis

Data on oil yield was analyzed using SPSS statistical program (SPSS Inc., Chicago, IL, USA). Analysis of variance, ANOVA, was performed to compare levels of oil yield in fish muscles, livers, and adipose tissues. Differences between means were tested for significance using the student's *t*-test. Differences between means were considered significant at $p < 0.05$.

Results and Discussion

Oil Contents of Fish Muscles, Livers, and Adipose Tissues

Nile perch muscles and adipose tissues contained higher oil contents (13.8 and 42.4%, respectively) than its liver (4.32%; Table 1). Lungfish livers and adipose tissues, on the contrary, contained higher oil content (39.6 and 53.4%, respectively) than the muscles

Table 1
Oil content (%) of muscles, livers, and adipose tissues of fish species of Lake Victoria

Fish species	Fish weight (kg)	Muscle oil (%)	Adipose tissue oil (%)	Liver oil (%)
Nile perch	3.43 ± 0.92^{3}	$13.8 \pm 0.42^{b,1}$	$42.4 \pm 1.38^{c,1}$	$4.32 \pm 0.31^{a,2}$
Lungfish	8.31 ± 1.04^{1}	$6.82 \pm 0.36^{a,2}$	$39.6 \pm 0.96^{b,2}$	$53.4 \pm 0.76^{c,1}$
Nile tilapia	1.35 ± 0.34^{4}	$5.23 \pm 0.47^{a,4}$	$32.7 \pm 1.73^{b,3,4}$	ND
Catfish A	4.25 ± 0.77^{3}	$6.25 \pm 0.46^{b,2,3}$	$31.4 \pm 0.85^{c,4}$	$4.14 \pm 0.28^{a,2,3}$
Catfish B	5.69 ± 0.79^{2}	$5.77 \pm 0.36^{b,3,4}$	$28.8 \pm 1.37^{c,5}$	$3.84 \pm 0.33^{a,3,4}$
Silver fish*	0.04 ± 0.00^{6}	3.16 ± 0.58^{5}	ND	ND
Victoria squeaker	0.43 ± 0.13^{5}	$6.39 \pm 0.61^{b,2}$	$34.4 \pm 0.86^{c,3}$	$3.62 \pm 0.31^{a,4}$

*Data derived from analysis of whole fish body.

Catfish A: *Clarias gariepinus*, Catfish B: *Bagrus docmac*, ND: not determined. Values in rows followed by a different superscript letter are significantly different ($p < 0.05$). Values in columns followed by a different superscript number are significantly different ($p < 0.05$).Values are averages of three replicates ± standard deviation.

(6.82%). Lungfish had exceptionally higher liver oil content (53.4%) than that from Nile perch, Nile tilapia, catfish A and B, and Victoria squeaker (3.62 to 4.32%). Nile tilapia, catfish A and B, and Victoria squeaker had higher adipose tissue oil contents (28.8 to 34.4%) than that from the respective livers and muscles (Table 1). Silver fish generally had low oil content (3.54%).

Based on fat content classification, Nile perch with high muscle oil content above 10% and liver oil content below 50% is regarded as a fatty fish (Bennion, 1980; Gurr, 1984; Rahnan et al., 1995). Nile tilapia, catfish A and B, lungfish, and Victoria squeaker with muscle fat content between 5 and 10% would be considered as semi-fatty fish (Bennion, 1980; Rahnan et al., 1995). Lungfish, on the other hand, would be classified as a lean fish given its high liver oil content (above 50%). Lean fish store 50 to 80% of their fat in the form of triacyglycerol in the liver. Silver fish with a low muscle fat content can be regarded as a low fat fish.

Fatty Acid Composition in Oils from Fish Muscles, Livers, and Adipose Tissues

Proportions of total saturated fatty acids (SFA) in oils from muscles of Nile perch, lungfish, Nile tilapia, catfish A and B, silver fish, and Victoria squeaker ranged from 30.1 to 40.1% of the total fatty acids (Table 2). The total amount of SFA in the seven fish species from Lake Victoria was within the higher side of the range reported (9.4 to 53.7%) for various freshwater fish (Ackman, 1967; Vlieg & Body, 1988; Wang et al., 1990). Palmitic (16:0) and stearic (18:0) acids were the major SFA accounting for 52.8 to 64.6% and 28.0 to 32.4% of total SFA, respectively. Myristic (14:0), heptadecanoic (17:0), and pentadecanoic (15:0) acids were also detected in appreciable amounts (Table 2). Oils from Victoria squeaker, Nile tilapia, catfish B, and silver fish had higher proportions of total SFA than that of catfish A, Nile perch, and lungfish (Table 2). The wide range in the proportions of SFA in fish oils can normally be attributed to diet (Moffat and McGill, 1993).

Oils from fish muscles contained high proportions of monounsaturated fatty acids (MUFA), ranging from 17.8% in Victoria squeaker to 26.5% in Nile perch. Asclepic acid (18:1n7) was found to be the major MUFA in oils from the seven fish species examined

Table 2
Fatty acid composition (% total fatty acids) of oils from muscles of fish species of Lake Victoria

	Fish species						
Fatty acids	Nile perch	Lungfish	Nile tilapia	Catfish A	Catfish B	Victoria squeaker	Silver fish*
SFA							
Myristic (14:0)	1.4 ± 0.3	3.2 ± 0.4	0.8 ± 0.4	1.2 ± 0.4	1.8 ± 0.7	1.1 ± 0.2	3.0 ± 0.4
Pentadecanoic (15.0)	0.8 ± 0.2	0.6 ± 0.1	1.2 ± 0.1	0.5 ± 0.1	0.7 ± 0.1	0.6 ± 0.1	0.7 ± 0.1
Palmitic (16:0)	20.4 ± 1.4	15.9 ± 1.2	25.6 ± 2.3	17.3 ± 2.2	23.3 ± 1.6	24.2 ± 0.9	21.7 ± 1.8
Heptadecanoic (17:0)	0.6 ± 0.3	1.0 ± 0.2	0.9 ± 0.2	0.7 ± 0.2	1.0 ± 0.2	1.2 ± 0.2	0.8 ± 0.4
Stearic (18:0)	9.9 ± 0.6	9.4 ± 0.5	11.1 ± 0.5	11.6 ± 0.7	12.0 ± 0.7	13.0 ± 1.0	10.8 ± 0.3
Total	33.1 ± 2.8	30.1 ± 2.4	39.6 ± 3.5	31.3 ± 3.6	38.8 ± 3.3	40.1 ± 2.4	37.0 ± 3.0
MUFA							
Palmitoleic (16:1n7)	5.6 ± 0.7	5.9 ± 0.8	2.1 ± 0.4	6.6 ± 0.6	4.2 ± 0.6	4.9 ± 0.3	5.5 ± 0.2
Erucic (17:1n9)	0.7 ± 0.3	0.8 ± 0.3	0.6 ± 0.2	0.6 ± 0.5	0.7 ± 0.2	0.8 ± 0.2	0.7 ± 0.4
Asclepic (18:1n7)	16.6 ± 0.8	12.3 ± 0.8	12.1 ± 0.5	8.5 ± 0.4	10.1 ± 0.7	6.9 ± 0.6	9.6 ± 0.6
Oleic (18:1n9)	3.6 ± 0.4	4.9 ± 0.6	3.9 ± 0.3	6.5 ± 0.7	5.4 ± 0.5	5.2 ± 0.4	6.3 ± 0.8
Total	26.5 ± 2.2	23.9 ± 2.5	18.7 ± 1.4	22.2 ± 2.2	20.4 ± 2.0	17.8 ± 1.5	22.1 ± 2.0
Omega-3 PUFA							
Alpha linolenic (18:3n3)	1.9 ± 0.4	3.5 ± 0.4	2.3 ± 0.3	4.2 ± 0.4	2.8 ± 0.4	3.7 ± 0.2	5.4 ± 0.5
Eicosapentaenoic (20:5n3)	4.5 ± 0.7	6.1 ± 0.3	3.7 ± 0.6	6.7 ± 1.0	3.9 ± 0.4	2.7 ± 0.2	5.2 ± 0.4
Docosapentaenoic (22:5n3)	2.0 ± 0.5	2.9 ± 0.2	1.3 ± 0.4	3.2 ± 0.3	2.3 ± 0.5	2.4 ± 0.4	4.2 ± 0.8
Docosahexaenoic (22:6n3)	15.9 ± 0.9	13.2 ± 1.3	13.7 ± 0.8	11.6 ± 0.6	11.0 ± 1.1	12.3 ± 0.8	6.4 ± 0.7
Total	24.3 ± 2.5	25.7 ± 2.2	21.0 ± 2.1	25.7 ± 2.3	20.0 ± 2.4	21.1 ± 1.6	21.2 ± 2.4
Omega-6 PUFA							
Gamma-linolenic (18:3n6)	1.2 ± 0.7	2.4 ± 0.6	1.3 ± 0.8	1.7 ± 0.6	1.2 ± 0.6	2.4 ± 1.1	3.6 ± 0.4
Arachidonic (20:4n6)	5.3 ± 0.7	6.6 ± 0.5	3.5 ± 0.4	10.7 ± 0.5	8.2 ± 0.4	6.1 ± 0.7	5.1 ± 0.9
Adrenic (22:4n6)	5.1 ± 0.3	4.2 ± 0.4	5.4 ± 0.7	3.7 ± 0.4	3.9 ± 0.2	6.1 ± 0.6	3.8 ± 0.3
Total	11.6 ± 1.5	13.2 ± 1.5	10.2 ± 1.9	16.1 ± 1.5	13.3 ± 1.2	14.6 ± 2.4	12.5 ± 1.7
Total PUFA	35.9 ± 4.0	38.9 ± 3.7	31.2 ± 4.0	41.8 ± 3.8	33.3 ± 3.6	35.7 ± 4.0	33.7 ± 4.1
PUFA/SFA	1.18	1.29	0.79	1.34	0.86	0.89	0.91
Omega-3/Omega-6	2.09	1.95	2.06	1.60	1.50	1.45	1.70

*Data derived from analysis of whole fish body.
Catfish A: *Bagrus docmac*, Catfish B: *Clarias gariepinus*, SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids. Values are averages of three replicates ± standard deviation.

and accounted for between 38.8 and 64.7% of total MUFA (Table 2). Oleic acid, 18:1n9 (3.6-6.5%); palmitoleic acid, 16:1n7 (2.1-6.6%); and erucic acid, 17:1n9 (0.6-0.8%) also occurred in substantial amounts. The MUFA of the C21 and C22 series were present in very low (< 0.1%) amounts. Levels of MUFA were close to those reported by Ackman (1967), Kinsella et al. (1977), and Aggelousis et al. (1991) for freshwater fish.

The total amounts of omega-3 PUFA (20.0 to 25.7%) in oils from fish muscles were found to be generally high (Table 2). Docosahexaenoic acid (DHA), 22:6n3; eicosahexaenoic acid (EPA), 20:5n3; docosapentaenoic acid (DPA), 22:5n3; and alpha-linolenic acid (ALA), 18:3n3 were the most dominant omega-3 PUFA in the oils (Table 2). The proportion of DHA was high in oils from Nile perch (15.9 ± 0.9%), Nile tilapia (13.7 ± 0.8%), lungfish (13.2 ± 1.3%), Victoria squeaker (12.3 ± 0.8%), and catfish (11.0 to 11.6%). In contrast, oils from the muscles of silver fish contained a comparatively low proportion (6.4 ± 0.7%) of DHA. The amounts of EPA in all the fish species ranged from 2.7 to 6.7% of the total fatty acids. Levels of DPA and ALA were in the range of 1.3 to 4.2 and 1.9 to 5.4%, respectively. Oils from Nile perch, Nile tilapia, Victoria squeaker, catfish A and B, and lungfish had amounts of omega-3 PUFA comparable to that reported for some temperate and tropical freshwater fish (Wang et al., 1990; Zenebe et al., 1998; Osman et al., 2007).

Oils from the muscles of all the fish types contained substantial amounts of omega-6 PUFA, mainly arachidonic acid (20:4n6), adrenic acid (22:4n6), and gamma-linolenic acid (18:3n6; Table 2). Arachidonic acid (20:4n6) was the major omega-6 PUFA in oils from all fish muscles (Table 2). Its concentration varied from 3.5% in Nile tilapia to 10.7% in catfish Hearn et al. (1987) and Zenebe et al. (1998) reported similar proportions of arachidonic acid in marine and tropical freshwater fish. Aggelousis et al. (1991) also reported gamma-linolenic acid to be a major omega-6 PUFA in freshwater fish. Adrenic acid, 22:4n6 (3.7 to 6.1%) and gamma-linolenic acid, 18:3n6 (1.2 to 3.6%) were also found in amounts close to that reported for tropical freshwater fish (Zenebe et al., 1998; Kwetegyeka et al., 2006).

The amounts of total omega-3 PUFA in oils from fish muscle, liver, and adipose tissue were essentially similar (Table 3). The concentration of total omega-3 PUFA ranged from 8.30 to 13.3 g/100 g in muscles, 8.4 to 12.7 g/100 g in adipose tissues, and 9.4 to 12.6 g/100 g in liver oils (Table 3). The DHA and EPA concentrations were generally high in oils from the different body parts of an individual fish. The concentration of DHA ranged from 2.7 g/100 g in oils from muscles of Victoria squeaker to 5.2 g/100 g in that of Nile tilapia (Table 3). The concentration of DHA in adipose tissues (3.1 to 5.3 g/100 g) and liver oils (2.3 to 4.6 g/100 g) were comparable to that observed in oils from fish muscles (1.9 to 5.2 g/100 g). The concentrations of ALA, EPA, and DPA in the oils from different fish body parts for any given fish type were also found to be similar (Table 3).

The ratio of omega-3 to omega-6 PUFA ranged from 1.45 in Victoria squeaker to 2.09 in Nile perch (Table 2). Ratio values were within the range of 1.2 to 2.9 reported for freshwater fish (Wang et al., 1990; Aggelousis et al., 1991). A high ratio of omega-3 to omega-6 PUFA in human and animal diets is critical for proper physiological performance (Connor, 2000; Simopoulos and Cleland, 2003). The PUFA to SFA ratios (0.79 to 1.18) observed in this study were above the value (0.58) recommended for dietary PUFA supplements (Food and Drug Administration [FDA], 1997). Fish lipids with PUFA to SFA ratio above 0.50 have been demonstrated to confer clinical benefits, attributed to mainly EPA and DHA (Gurr, 1984). Ratio values of PUFA to SFA, in this study, were higher than that reported for some marine and tropical fish (Zenebe et al., 1998; Osman et al., 2007). Based on the high ratios of omega-3 to omega-6 PUFA, Nile perch, Nile tilapia, Victoria squeaker, catfish A and B, lungfish, and silver fish can be regarded as good dietary sources of omega-3

Table 3
Omega-3 polyunsaturated fatty acids concentration in different body parts of fish from Lake Victoria

Body parts	Fish species	Omega-3 fatty acids (g/100 g crude oil)				
		ALA	EPA	DPA	DHA	Σ omega-3 PUFA
Muscle	Nile perch	2.5 ± 1.2	4.8 ± 0.6	0.6 ± 0.2	4.9 ± 0.9	12.8 ± 2.9
	Lungfish	2.9 ± 0.9	2.3 ± 0.6	0.5 ± 0.2	4.4 ± 0.8	10.1 ± 2.5
	Nile tilapia	2.7 ± 0.8	5.0 ± 1.4	0.4 ± 0.1	5.2 ± 1.2	13.3 ± 3.5
	Catfish A	2.9 ± 0.5	3.1 ± 0.2	0.9 ± 0.3	2.5 ± 0.3	9.4 ± 1.3
	Catfish B	4.4 ± 0.4	2.9 ± 0.8	0.7 ± 0.2	3.0 ± 0.8	11.0 ± 2.2
	Victoria squeaker	2.1 ± 0.4	2.8 ± 0.3	0.7 ± 0.1	2.7 ± 0.3	8.3 ± 1.1
	Silver fish*	2.9 ± 0.7	3.0 ± 1.1	1.3 ± 0.3	1.9 ± 0.6	9.1±2.7
Adipose tissue	Nile perch	2.6 ± 0.7	4.3 ± 0.7	0.5 ± 0.2	5.3 ± 1.5	12.7 ± 3.1
	Lungfish	2.8 ± 1.2	2.9 ± 0.4	0.7 ± 0.2	4.5 ± 0.8	10.9 ± 2.6
	Nile tilapia	3.0 ± 0.6	2.1 ± 0.5	0.9 ± 0.3	4.3 ± 0.3	10.3 ± 1.7
	Catfish A	2.6 ± 0.4	3.1 ± 0.3	0.7 ± 0.3	3.2 ± 0.8	9.6 ± 1.8
	Catfish B	3.2 ± 1.0	2.0 ± 0.4	0.8 ± 0.2	2.8 ± 0.5	8.8 ± 2.1
	Victoria squeaker	1.9 ± 0.5	2.5 ± 0.3	0.9 ± 0.2	3.1 ± 0.7	8.4 ± 1.7
Liver	Nile perch	2.1 ± 0.4	4.2 ± 0.6	0.9 ± 0.4	4.6 ± 1.5	11.8 ± 2.9
	Lungfish	3.4 ± 0.8	2.6 ± 0.3	1.2 ± 0.3	3.0 ± 0.4	10.2 ± 1.8
	Nile tilapia	2.7 ± 0.4	4.7 ± 1.1	0.6 ± 0.2	4.6 ± 0.9	12.6 ± 2.6
	Catfish A	2.6 ± 0.7	3.2 ± 1.2	0.9 ± 0.5	2.7 ± 0.4	9.4 ± 2.8
	Catfish B	3.8 ± 1.2	3.2 ± 0.4	0.9 ± 0.2	2.3 ± 0.3	10.2 ± 2.1

*Data derived from analysis of whole fish body.

A: *Bagrus docmac*, B: *Clarias gariepinus*, ALA: alpha linolenic acid, DPA: docosapentaenoic acid, EPA: eicosapentaenoic acid, DHA: docosahexaenoic acid, PUFA: polyunsaturated fatty acids. Values are averages of three replicates ± standard deviation. Note: Livers of silver fish and Victoria squeaker and the blubber of silver fish were not considered because of their very small size.

PUFA. Production of fish oils from the seven fish species could therefore be promoted as a means to provide omega-3 supplements. It has previously been demonstrated that oils from fish caught in Lake Victoria had low levels of contaminants (Ogwok et al., 2009). Thus, it is likely that the oils from the seven species studied would meet the regulatory limits for contaminants. Traditionally, the fish species studied are widely consumed, mainly in the form of a stew made from fresh fish, except for silver fish which is usually dried. The fish species should therefore make a substantial contribution to dietary omega-3 intake of the local population.

Conclusion

Fish oils from the seven freshwater fish species of Lake Victoria (Uganda) are good sources of omega-3 PUFA, particularly DHA and DPA, with amounts beneficial for human health. The quality of the oils is not influenced by fish body parts since no important variation in amounts of omega-3 PUFA was demonstrated. Based on the oil content and amounts of omega-3 PUFA, it can be concluded that lungfish liver and the adipose tissues of Nile perch, Nile tilapia, Victoria squeaker, and catfish (A and B) are good raw materials for production of fish oils.

References

Ackman, R. G. (1967). Characteristics of the fatty acid composition and biochemistry of some freshwater fish oils and lipids in comparison with marine oils and lipids. Comp. Biochem. Physiol. 22: 907–922.

Aggelousis, G., and Lazos, S. E. (1991). Fatty acid composition of the lipids from eight freshwater fish species from Greece. J. Food Compos. Anal. 4: 68–76.

Bennion, M. (1980). Introductory Foods. 7th ed. New York: Macmillan.

Connor, W. E. (2000). Importance of n-3 fatty acids in health and disease. Am. J. Clin. Nutr. 71(1): 171S–175S.

Dolecek, T. A. (1992). Epidemiological evidence of relationships between dietary polyunsaturated fatty acids and mortality in the multiple risk factor intervention trial. Proc. Soc. Exp. Biol. Med. 200: 177–182.

FDA. (1997). Food labelling: Requirements for nutrient content claims, health claims, and statements of nutritional support for dietary supplements. Federal Register—Rules and Regulations 62(108): 49859–49868.

Grahl-Nielsen, O., and Barnung, T. (1985). Variations in the fatty acid profile of marine animals caused by evaporation and developmental changes. Mar. Exp. Res.17: 218–221.

Gurr, M. I. (1984). Fats in health and diseases. In: Roles of Fat and Nutrition. Barking, Essex, UK: Elsevier Applied Science Publishers. pp. 117–161.

Harper, C. R., and Jacobson, T. A. (2001). The fats of life: The role of n-3 fatty acids in prevention of coronary heart disease. Arch. Intern. Med. 161: 2185–2192.

Harris, W. S. (1997). N-3 fatty acids and serum lipoproteins: Human studies. Am. J. Clin. Nutr. 65 (5): 1645S–1654S.

Harris, W. S., Mozaffarian, D., Rimm, E., Kris-Etherton, P., Rudel, L. L., Appel, L. J., Engler, M. M., Engler, M. B., and Sacks, F. (2009). Omega-6 fatty acids and risk for cardiovascular disease. Circulation 119: 902–907.

Hearn, T. L., Sgoutas, S. A., Hearn, J. A., and Sgoutas, D. S. (1987). Polyunsaturated fatty acids and fat in fish flesh for selecting species for health benefits. J. Food Sci. 52: 1209–1211.

Henderson, R. J., and Tocher, D. R. (1987). The lipid composition and biochemistry of freshwater fish. Prog. Lipid Res. 26: 281–347.

Kinsella, J. E., Shimp, J. L., Mai, J., and Weihrauch, J. (1977). Fatty acid content and composition of freshwater finfish. J. Am. Oil Chem. Soc. 54: 424–429.

Kwetegyeka, J., Mpango, G., and Grahl-Nielsen, O. (2006). Fatty acid composition of muscle and heart tissue of Nile perch (*Lates niloticus*) and Nile tilapia (*Orechromis niloticus*) from various populations in Lakes Victoria and Kioga, Uganda. Afr. J. Aqua. Sci. 31(2): 279–304.

Leaf, A., and Weber, P. C. (1988). Cardiovascular effects of n-3 fatty acids. N. Engl. J. Med. 318: 549–557.

Mensink, R. P., and Katan, M. B. (1992). Effect of dietary cis- and trans-fatty acids on serum lipids and lipoproteins: A meta-analysis of 27 trials. J. Am. Heart Assoc. 12: 911–919.

Moffat, C. F., and McGill, A. S. (1993). Variability of the composition of fish oils: Significance for the diet. Proc. Nutr. Soc. 52: 441–456.

Ogwok, P., Muyonga, J. H., and Sserunjogi, M. L. (2008). Fatty acid profile and stability of oil from the belly flaps of Nile perch (*Lates niloticus*). Food Chem. 108: 103–109.

Ogwok, P., Muyonga, J. H., Sserunjogi, M. L., Amegovu, A. K., and Makokha, V. (2009). Variation in chemical composition of oils from Nile perch (*Lates niloticus*) belly flaps with capture site and season. J. Aquat. Food Prod. T. 18: 331–334.

Osman, F., Jaswir, I., Khaza'ai, H., and Hashim, R. (2007). Fatty acid profile of fin fish in Langkawi Island, Malaysia. J. Oleo Sci. 56(3): 107–113.

Polvi, S. M., and Ackman, R. G. (1992). Atlantic salmon (*Salmo salar)* muscle lipids and their response to alternative dietary fatty acid sources. J. Agricult. Food Chem. 40: 1001–1007.

Rahnan, S. A., Huah, T. S., Nassan, O., and Daud, N. K. (1995). Fatty acid composition of some Malaysian freshwater fish. Food Chem. 54(1): 45–49.

Saify, Z. S., Akhtar, S., Khan, K. M., Perveen, S., Ayattollahi, S. A M., Hassan, S., Arif, M., Haider, S. M., Ahmad, F., Siddiqui, S., & Khan, M. Z. (2003). A study on fatty acid composition of fish liver oil from two marine fish, *Eusphyra blochii and Carcharhinus bleekeri*. Turk. J. Chem. 27: 251–258.

Simopoulos, A. P., and Cleland, L. G. (2003). Omega-6 and omega-3 essential fatty acid ratio: The scientific evidence. World Rev. Nutr. Diet. 92: 1–13.

Turon, F., Rwabwogo, B., Baréa, B., Pina, M., and Graille, J. (2005). Fatty acid composition of oil extracted from Nile perch (*Lates niloticus*) head. J. Food Compos. Anal. 18(7): 717–722.

Vlieg, P., and Body, D. R. (1988). Lipid contents and fatty acid composition of some New Zealand freshwater finfish, shellfish, and roes. Mar. Freshwater Res. 22: 151–162.

Wang, Y. P, Miller, L. A., Perren, M., and Addis, P. B. (1990). Omega-3 fatty acids in Lake Superior fish. J. Food Sci. 55(1): 71–73.

Yongo, E., Keizire, B. B., and Mbilinyi, H. G. (2005). Socio-economic impact of fish trade. In: The State of the Fisheries Resources of Lake Victoria and Their Management. Jinja, Uganda: Lake Victoria Fisheries Organisation. pp.132–138.

Zenebe, T., Ahlghren, G., Gustaffson, I. B., and Boberg, M. (1998). Fatty acid content of some freshwater fish of commercial importance from tropical lakes in the Ethiopian rift valley. J. Fish Biol. 53: 987–1005.

Zock, P. L., and Katan, M. B. (1998). Linoleic acid intake and cancer risk: A review and meat-analysis. Am. J. Clin. Nutr. 68: 142–153.