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# Variation in Chemical Composition of Oils from Nile Perch (*Lates niloticus*) Belly Flaps with Capture Site and Season

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*Fatty material from Nile perch belly flaps, a major processing by-product, was assessed for variation in fat content, fatty acid composition, vitamin A content, and level of contaminants in relation to capture site and season. Nile perch from Lake Victoria had higher material yield and omega-3 fatty acids (FAs) but lower content of vitamin A than those from Lake Albert. Levels of omega-3 FAs (4.36–20.20%) and vitamin A (2.83–7.88 mg/100 g of oil) were generally high. Levels of lead and cadmium showed significant variation with site. Material weight and vitamin A contents were higher, whereas FAs were lower in fish captured during the dry season than those in the wet season.*

*KEYWORDS Nile perch, fish oil, vitamin A, omega-3 fatty acids, heavy metals, pesticides*

## INTRODUCTION

Fatty material from Nile perch belly flaps, generated from filleting, is estimated to account for more than 10% of the total fish body weight (Ogwok

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et al., 2008). Oils extracted from by-products of Nile perch processing have also been found to contain high levels of essential fatty acids (EFAs) and antioxidant vitamins (Turon et al., 2005; Ogwok et al., 2008). Data on variation of the biochemical components of Nile perch in relation to the biological and environmental conditions under which the fish grows are still limited. Moreover, the life cycle of Nile perch comprises a period of foraging, characterized by intensive feeding, that could affect the overall amount of lipid components (Rabour et al., 2003).

Fish lipids may vary in fatty acid profile depending on capture season (Huynh et al., 2007), site (Joseph, 1985), and fish age (Ogwok et al., 2008). Non-spawning fish have been found to contain substantial amounts of EFAs (Huynh et al., 2007). Variation in fatty acid (FA) composition during different capture seasons is mainly related to physiological demand and feeding pattern (Huynh et al., 2007). In general, limited food intake during reproduction is associated with changes in the FA profile of lipids. Differences in amounts of FAs that occur with location have been shown to depend mainly on food availability and composition (Joseph, 1985). Lipid contents of fish may therefore differ significantly depending on both biological and environmental factors (Oliveira et al., 2003).

Fish products may contain substantial amounts of environmental contaminants, such as heavy metals, organochlorine, and organophosphorus pesticides. Levels of these contaminants vary depending on the source of water and capture season (Das et al., 2002; Yilmaz and Yilmaz, 2007). Fish inhabiting highly contaminated waters have been found to accumulate substantial levels of contaminants (Das et al., 2002). Large fish and predators are particularly more likely to contain high levels of heavy metals (Storelli and Marcotrigiano, 2001) and pesticide residues (Das et al., 2002) due to bioaccumulation. Seasonal changes in amounts of environmental contaminants in fish have also been reported (Das et al., 2002; Yilmaz and Yilmaz, 2007). Differences in levels of contaminants have been attributed to changes in biological cycles of the fish. Pesticide residues in fish from highly contaminated waters are particularly found in substantial amounts during non-spawning periods when the fish have a high accumulation of fat (Das et al., 2002). Lake Albert, which contains a high Nile perch population, is considered pristine since it is located far from major industrial sites. Lake Victoria, however, has experienced consequences of insufficient treatment of industrial wastes (Muwanga and Barifaijo, 2006) and large-scale application of agrochemicals (Wasswa and Kiremire, 2004). Nile perch, a voracious predator with a wide food base, is more likely to be exposed to significant amounts of environmental contaminants. Limited data exists on the variation of environmental contaminants and nutritional components of Nile perch due to biological and environmental factors. In this study, materials from belly flaps of Nile perch obtained from Lake Victoria and Lake Albert during dry and wet seasons were evaluated to determine the differences in fatty

material yield, fat content, vitamin A content, FA composition, and level of contaminants.

## MATERIALS AND METHODS

### Sampling and Sample Preparation

Nile perch (*Lates niloticus)* from Lake Victoria and Lake Albert were obtained from a fish processing plant (Ngege fish processing industry, Kampala, Uganda). Thirty samples of Nile perch, weighing between 10–30 kg, were collected from Lake Victoria and Lake Albert during the dry season (December 2007 to January 2008). For comparison, samples of Nile perch were also obtained from Lake Victoria and Lake Albert during the wet seasons (August 2006 to November 2006 and August 2008 to November 2008, respectively) to establish the effect of season on fat content, vitamin A content, fatty acid composition, and level of contaminants. Fatty materials from belly flaps were obtained from the fish samples, after filleting, by scraping until the weight of materials was constant. Belly flap materials were weighed to determine the material index (percent material weight in relation to total fish body weight) and analyzed for lipid content. Samples (20 to 1650 g) were packed separately in black polyethylene bags and covered with layers of ice (about 1.5-cm thick) contained in black plastic boxes.



### Determination of Lipid Content

Lipid content of fatty material was determined by Soxhlet extraction using petroleum-ether as described by AOAC (1999) method no. 948.16.

### Extraction of Oil

Fatty material was homogenized at ambient temperature using a Waring blender (Patterson Scientific, Blender 800E, USA). Oil was extracted according to the procedure described by Ogwok et al. (2008). Dried oil was stored at −20°C in brown vials and analyzed within a week for vitamin A, FAs, and environmental contaminants.

### Determination of Fatty Acid Profile

Fatty acid profile of Nile perch oil was determined quantitatively using gas chromatography (GC; PerkinElmer, Norwalk, CT, USA) in accordance with AOCS (1998) method Ce 1b-89. Boron trifluoride ($BF_3$) and methanol mixture (10% wt/vol) was used for preparation of fatty acid methyl ester

(FAME). Samples were prepared for analysis according to the procedure described by Ogwok et al. (2008). Analysis was performed using GC equipped with a fused silica capillary column (cyanopropylsiloxane, CD-Sil 88, 50 m × 0.22 mm; i.d., 0.2-μm film; Chrompack, Middleburg, The Netherlands). The mass spectrometer (MS) was equipped with an electron impact (EI) ionizer (1600 electron multiplier [EM] volts) and a quadruple effect mass analyzer operating in total ion mode (50 to 600 atomic mass units). The oven was heated from 150 to 225°C at a temperature increase rate of 5°C per min and held for 10 min. The temperature of the injector and flame-ionization detector (FID) was maintained at 250°C. Inlet pressure of the carrier gas (hydrogen) was held at 85 kPa. Percentages of peak area obtained were divided by the relative molecular weight of respective fatty acids methyl ester to obtain moles percent of fatty acids.

## Determination of Vitamin A

The vitamin A content of oil was analyzed by AACC (2004) method 86-06 using high-pressure liquid chromatography (PerkinElmer, Series 200 LC, UK) equipped with a photometric detector and a reverse-phase column C8, 5-μm (4 mm × 250 mm), for *trans* and *cis* isomers of retinol. A tetrahydrofuran and ethanol mixture was used for preparing a sample solution. The oil solution and vitamin A working standards were prepared for analysis as described earlier (Ogwok et al., 2008).

## Analysis of Organochlorine Pesticide Residues

Nile perch belly flap oil was analyzed for chlorinated pesticides (dichlorodiphenyltrichloroethane [DDT], aldrin, hexachlorocyclohexane [$\alpha$-HCH], dieldrin, endrin, heptachlor and their metabolites, $\beta$-HCH, 2, 4′-dichlorodiphenyldichloroethane [2, 4′-DDD], 4, 4′-DDD, 4, 4′-DDE, 2, 4′-DDT, 4, 4′-DDT, heptachlor epoxide, lindane, and nonacachlor) and chlorofenvinphos according to the method described by Hollamby et al. (2004). Crude belly oil (10 g) was dehydrated by mixing with anhydrous sodium sulphate (100 g) in a beaker. A dehydrated sample was then transferred to a beaker and dissolved in a mixture of ethyl-ether and petroleum-ether at a ratio of 1:1. The mixture was then warmed in a water-bath at 60°C for approximately 5 min. The process of ether extraction was repeated twice, and the combined extract dried over a warm water-bath. Subsequently, the dry extract was dissolved in hexane, and 1mL of the solution was subjected to a Silica Gel column (5 g Silica Gel 60, 9-mm column i.d.) for purification. A blank sample of refined Nile perch oil that was pretested and found to have no detectable pesticide residues was similarly prepared and spiked at 0.1 ppm.

Standard curve (area versus concentration) was prepared using an organochlorine pesticides mixture containing 20 analytes in a hexane:toluene

(50:50) mixture at 2000 μg/mL. Standard solution was prepared by serial dilution of the standard reagents. Linear standard curves in the range of 0.002 to 0.5 ppm were used for quantification. Final duplicate extracts (1 μL) were analyzed on a fused silica capillary column (100% dimethylpolysiloxane 6′ × 0.25″ i.d., 0.52 μm) by gas chromatography (PerkinElmer, Clarus 500, USA) coupled with high-resolution mass spectrometry.

### Analysis of Heavy Metals (Mercury, Lead, Arsenic, and Cadmium)

Levels of mercury, lead, arsenic, and cadmium in Nile perch oil were determined using an atomic absorption spectrometer (PerkinElmer, Norwalk, CT, USA) as described by AOAC (1999) method 986.15. Oil (5 g) was dissolved in lecithin solution in cyclohexane and vaporized in a graphite furnace connected to an atomic absorption spectrometer (AAS). Lead was determined at 283.3 nm, arsenic at 840 nm, and cadmium at 228.8 nm. The sample (2 g) for mercury analysis was digested using a mixture of concentrated nitric and sulphuric acids (1:1) (10 mL). The oxidized sample was subjected to a temperature of 60°C under reflux for 5 h. Acetone was added to make up a volume of 100 mL before analysis. Quantitative analysis of Hg was carried out using a cold vapor AAS. Mercury analysis was performed after reduction using tin (II) chloride (0.2 mL) at 253.7 nm. Mercury (II) chloride, lead nitrate, sodium arsenate, and cadmium sulphate were used for preparing mercury, lead, arsenic, and cadmium standards, respectively.



### Statistical Analysis

Student's *t* test was used to compare the material weight, fat content, oil yield, vitamin A content, fatty acid composition, and level of environmental contaminants in Nile perch belly flaps. These parameters were compared in fish from the two different capture sites (Lake Victoria and Lake Albert) and seasons (dry and wet seasons). Data collected were analyzed using SPSS statistical program (SPSS Inc., Chicago, IL, USA). Differences in the means were considered significant at $p < 0.05$.

## RESULTS AND DISCUSSION

### Variation in Material Weight and Fat Content

The weights of fatty material from Nile perch belly flaps varied significantly ($p < 0.05$) with capture site (Table 1). The material index of Nile perch from Lake Victoria (10.42 ± 2.30%) was higher than that from Lake Albert (3.05 ± 1.28%). No differences ($p < 0.05$) were observed in lipid contents and oil yields of belly flaps of fish from Lake Victoria and Lake Albert. Variation in

**TABLE 1** Variation in Fatty Material Weight, Fat Content, and Oil Yield of Nile Perch Belly Flaps with Capture Site and Season

| | Lake Victoria Nile perch | | Lake Albert Nile perch | |
|---|---|---|---|---|
| Sampling period | Wet season | Dry season | Wet season | Dry season |
| Av. body weight (kg) | $25.60 \pm 1.34^{a}$ | $12.97 \pm 0.88^{b}$ | $11.92 \pm 0.59^{b}$ | $23.08 \pm 4.34^{a}$ |
| Fatty materials (g) | $524.60 \pm 197.35^{b}$ | $1338.33 \pm 205.93^{a}$ | $225.11 \pm 184.4^{b}$ | $896.67 \pm 676.78^{ab}$ |
| Fatty material index (% BW) | $2.10 \pm 0.79^{b}$ | $10.42 \pm 2.30^{a}$ | $1.92 \pm 1.56^{b}$ | $3.05 \pm 1.28^{b}$ |
| Lipid (%) | $75.36 \pm 5.94^{a}$ | $88.95 \pm 4.97^{a}$ | $77.24 \pm 6.67^{a}$ | $96.65 \pm 2.93^{a}$ |
| Oil yield (g/100 g) | $69.08 \pm 8.69^{a}$ | $77.07 \pm 3.36^{a}$ | $67.06 \pm 7.22^{a}$ | $79.00 \pm 1.94^{a}$ |

Values in rows followed by a different superscript are significantly different ($p < 0.05$). BW: body weight. Values are averages of three replicates ($n = 30$) ± standard deviation.



fatty material yield of Nile perch belly flaps with fish capture site could be due to differences in food availability and dietary caloric value. Nile perch from Lake Victoria feed predominantly on *Rastrineobola argentea*, *Caridina nilotica*, Anisoptera nymphs, Nile perch juveniles, haplochromines, and cichlids (tilapias), depending on their abundance (Ogutu-Ohwayo, 2004). Lake Albert Nile perch, on the other hand, feed on *Alestes* spp., *Hydrocynus* spp., *Polypterus senegacensis, Bagrus* spp., and Mormyrids (Ogutu-Ohwayo, 2004). Nile tilapia (*Oreochromis niloticus)* and *R. argentea*, the major prey of Nile perch from Lake Victoria, account for approximately 30% of the total fish landed in Uganda (Yongo et al., 2005). In addition, *O. niloticus* and *R. argentea* have been found to have high fat content (3.1 and 5.1% of wet body weight, respectively; Masa, 2007). In contrast, the population of catfish (particularly *Bagrus docmac)*, a major prey for Lake Albert Nile perch together with other small pelagic fish species, accounts for ≤ 10% of total fish biomass (Yongo et al., 2005). This is likely to provide an inadequate source of food for Nile perch from Lake Albert despite the high fat content of *B. docmac* (5.7%; Masa, 2007). This may explain the observation that Nile perch from Lake Victoria, which feed heavily on *R. argentea* and *O. niloticus*, had higher fatty material yield than that from Lake Albert.

Nile perch from Lake Victoria, obtained during different periods, showed a significant difference in fatty material yield (Table 1). The material index was found to be lowest during the wet season with values increasing nearly five times in the dry season. Seasonal variation in fatty material weight of Nile perch belly flaps could mainly be attributed to dietary and physiological factors (Huynh et al., 2007). Nile perch normally feed throughout the dry season and limit food intake during spawning (Rabour et al., 2003). Spawning, which occurs within the wet season for Nile perch, also involves significant use of energy for movement and development of

reproductive organs. This may explain the low amounts of fat deposited in the belly flaps of Nile perch during the wet season.

## Variation in Vitamin A Content

Nile perch belly flaps contained high amounts of vitamin A (2.83 to 7.88 mg/100 g of oil). The content of vitamin A in belly flap oils varied significantly ($p < 0.05$) with capture site. Nile perch from Lake Albert had higher levels (7.88 ± 1.74 mg/100 g of oil) of vitamin A than those from Lake Victoria (2.98 ± 1.28 mg/100 g of oil). Diet contributes significantly to variability in vitamin A content since fish do not synthesize vitamin A (Lovern et al., 1933). Lake Victoria contains higher fish biomass than Lake Albert and is therefore likely to provide an adequate and a wide spectrum of food for Nile perch (Yongo et al., 2005).

Belly flap oils of Nile perch captured from Lake Albert during the dry season had a higher ($p < 0.05$) level of vitamin A (7.88 ± 1.74 mg/100 g of oil) than those captured in the wet season (2.83 ± 1.49 mg/100 g of oil). Vitamin A content of belly flap oils of Nile perch from Lake Victoria did not show any significant differences ($p < 0.05$) with season (2.98 ± 1.28 and 5.28 ± 2.14 for dry and wet seasons, respectively). Variation in vitamin A concentrations in oils from Nile perch belly flaps during the dry and wet seasons could be linked to food supply and intake and physiological demand. Nile perch spawn during the two, long, wet seasons of March to June and October to December (Rabour et al., 2003). During spawning, fat reserves are utilized for development of gonads. Rapid reduction in fat reserves during spawning involves a substantial decrease in the amount of lipids (Lovern et al., 1933). In addition, during spawning migration, Nile perch limit food intake (Rabour et al., 2003). Based on these facts, the amount of vitamin A in Nile perch belly flap oil is expected to be higher during the dry season because of the more intensive feeding experienced during that period.

## Variation in Fatty Acid Composition

Fatty acid profile of oils from Nile perch belly flaps varied ($p < 0.05$) with site (Table 2). Nile perch from Lake Victoria contained higher amounts of heptadecanoic (17:0), heptadecenoic (17:1), docosapentaenoic (22:5, n-3), and docosahexaenoic (22:6, n-3) acids than Lake Albert fish. No significant difference ($p < 0.05$) was noted in levels of total saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs) with capture site. Oil from Lake Victoria Nile perch contained a higher proportion of PUFAs, mainly omega-3 FAs, than that from Lake Albert Nile perch. The concentration of docosahexaenoic acid (DHA) in Nile perch from Lake Victoria (5.63 ± 0.57%) was higher than that from Lake Albert (2.40 ± 0.56%). Levels of total omega-6 and omega-9 FAs in Nile perch belly flap oils were not significantly different

($p < 0.05$) among fish from different sites. Nile perch from Lake Victoria contained a higher ratio of omega-3 to omega-6 FAs in belly flap oil than those from Lake Albert (Table 2). Consumption of foods with high ratios of these PUFAs is known to lower the level of blood cholesterol (Richardson,

**TABLE 2** Variation in Fatty Acid Composition of Oils from the Belly Flaps of Nile Perch with Capture Site and Season

| | Concentration (%) | | | |
|---|---|---|---|---|
| | Lake Victoria Nile perch | | Lake Albert Nile perch | |
| Fatty acids | Wet season | Dry season | Wet season | Dry season |
| Sampling period | | | | |
| Myristic (14:0) | 3.30 ± 0.17$^{b}$ | 6.73 ± 1.29$^{ab}$ | 6.97 ± 0.60$^{a}$ | 8.20 ± 0.26$^{a}$ |
| Myristoleic (14:1) | < 0.50 | 0.87 ± 0.21$^{a}$ | < 0.50 | 0.60 ± 0.00$^{a}$ |
| Palmitic (16:0) | 22.77 ± 0.32$^{b}$ | 26.73 ± 1.11$^{a}$ | 25.90 ± 0.20$^{a}$ | 27.13 ± 2.20$^{a}$ |
| Palmitoleic (16:1, n-7) | 12.87 ± 1.05$^{c}$ | 15.53 ± 1.82$^{abc}$ | 18.83 ± 0.47$^{a}$ | 16.67 ± 0.76$^{b}$ |
| Heptadecanoic (17:0) | < 0.50 | 1.13 ± 0.06$^{a}$ | < 0.50 | 0.73 ± 0.06$^{b}$ |
| Heptadecenoic (17:1) | < 0.50 | 0.97 ± 0.06$^{a}$ | < 0.50 | 0.63 ± 0.06$^{b}$ |
| Stearic (18:0) | 7.30 ± 0.44$^{a}$ | 6.73± 0.8$^{a}$ | 7.0 ± 0.10$^{a}$ | 7.73 ± 0.76$^{a}$ |
| Asclepic (18:1, n-7) | < 0.50 | 3.47 ± 0.70$^{a}$ | < 0.50 | 4.07 ± 0.40$^{a}$ |
| Oleic (18:1, n-9) | 21.07 ± 2.40$^{ab}$ | 18.57 ± 2.10$^{b}$ | 25.08 ± 1.1$^{a}$ | 21.13 ± 2.27$^{ab}$ |
| Linoleic (18:2, n-6) | 2.00 ± 0.10$^{a}$ | 1.77 ± 0.45$^{a}$ | 1.40± 0.20$^{a}$ | 1.77 ± 0.23$^{a}$ |
| Alpha-linolenic (18:3, n-3) | 1.73 ± 0.12$^{a}$ | 1.80 ± 0.20$^{a}$ | 1.17 ± 0.31$^{a}$ | 1.53 ± 0.23$^{a}$ |
| Eicosenoic (20:1, n-9) | < 0.50 | 0.70 ± 0.14$^{a}$ | < 0.50 | 0.60 ± 0.14$^{a}$ |
| Eicosatrienoic (20:3, n-6) | < 0.50 | 1.53 ± 0.12$^{a}$ | < 0.50 | 1.43 ± 0.32$^{a}$ |
| Eicosapentaenoic (20:5, n-3) | 3.67 ± 0.29$^{a}$ | 2.17 ± 0.23$^{b}$ | < 0.50 | 1.10 ± 0.46$^{b}$ |
| Docosapentaenoic (22:5, n-3) | 5.40 ± 0.36$^{a}$ | 3.47 ± 0.15$^{b}$ | < 0.50 | 2.27 ± 0.40$^{c}$ |
| Docosahexaenoic (22:6, n-3) | 9.40 ± 0.62$^{a}$ | 5.63 ± 0.57$^{b}$ | 3.19 ± 0.59$^{c}$ | 2.40 ± 0.56$^{c}$ |
| Others* | 10.50 ± 0.61$^{a}$ | 2.33 ± 0.35$^{c}$ | 8.54 ± 0.60$^{b}$ | 2.00 ± 0.70$^{c}$ |
| Total saturated fatty acids | 33.37 ± 0.71$^{c}$ | 41.33 ± 1.62$^{a}$ | 40.57 ± 0.78$^{b}$ | 43.80 ± 1.65$^{a}$ |
| Total monounsaturated fatty acids | 33.93 ± 1.38$^{c}$ | 39.97 ± 1.03$^{bc}$ | 45.13 ± 0.70$^{a}$ | 43.70 ± 1.25$^{ab}$ |
| Total polyunsaturated fatty acids | 22.20 ± 1.32$^{a}$ | 16.37 ± 0.70$^{b}$ | 5.76 ± 0.41$^{c}$ | 10.50 ± 2.13$^{c}$ |
| Total ω-3 fatty acids | 20.20 ± 1.25$^{a}$ | 13.07 ± 0.60$^{b}$ | 4.36 ± 0.57$^{c}$ | 7.30 ± 1.64$^{c}$ |
| Total ω-6 fatty acids | 2.00 ± 0.10$^{ab}$ | 3.30 ± 0.56$^{a}$ | 1.40 ± 0.20$^{b}$ | 3.20 ± 0.50$^{a}$ |
| Total ω-9 fatty acids | 21.07 ± 2.40$^{b}$ | 19.03 ± 2.5$^{b}$ | 25.80 ± 1.11$^{a}$ | 21.73 ± 2.21$^{ab}$ |
| Total PUFAs/Total SFAs | 0.67 ± 0.06$^{a}$ | 0.40 ± 0.03$^{b}$ | 0.14 ± 0.01$^{c}$ | 0.24 ± 0.06$^{bc}$ |
| Total ω-3 FAs/Total ω-6 FAs | 10.10 ± 0.43$^{a}$ | 4.04 ± 0.76$^{b}$ | 3.19 ± 0.81$^{bc}$ | 2.27 ± 0.17$^{c}$ |

*Individual Fatty acids < 0.50% total fatty acids: 4:0, 6:0, 8:0, 10:0, 11:0, 12:0,13:0, 14:1, 18:3, n-6, 20:0, 20:2, 20:4, n-6, 22:0, 22:1, n-9, 22:2, 23:0, 24:0, & 24:1. Values in rows followed by a different superscript are significantly different ($p < 0.05$). Values are averages of three replicates ($n = 30$) ± standard deviation. FA: fatty acid; SFAs: saturated fatty acids; PUFAs: polyunsaturated fatty acids.

1984). Differences in concentrations of FAs in Nile perch from different sites could mainly be attributed to their diets (Ogutu-Ohwayo, 2004). Nile tilapia, the most abundant prey of Nile perch in Lake Victoria, contain high amounts of omega-3 FAs (32.0 ± 1.0%) comparable to that of *Bagrus docmac* (35.0 ± 1%), common in Lake Albert (Kwetegyeka et al., 2008). *Rastrineobola argentea*, which is the third most important fish species in Uganda and commonly found in Lake Victoria, also contain substantial amounts (22.0 ± 2.4%) of omega-3 FAs (Masa, 2007). The difference in proportions of omega-3 FAs in Nile perch from different capture sites could mainly be attributed to food abundance. Studies have shown that the fatty acid profile of fish tissue may vary depending on diet (Moffat & McGill, 1993; Zenebe et al., 1998). Nile perch from Lake Victoria, with its high population of fish prey, is therefore likely to have higher amounts of omega-3 FAs compared to those from Lake Albert.

The amounts of FAs in belly flap oils derived from Nile perch was found to differ significantly ($p < 0.05$) with the capture season (Table 2). The oils contained a higher ($p < 0.05$) proportion of total SFAs during the dry period than during the wet season. The low levels of SFAs, particularly palmitic acid (16:0), in fish lipids during the wet period could be a consequence of increased energy demand (Huynh et al., 2007). Reduction in the amounts of palmitic acid in Nile perch during the wet season corresponded to spawning (Rabour et al., 2003). SFAs are major sources of energy for the fish, especially during formation of reproductive organs (Henderson et al., 1984). In addition, Nile perch starve during spawning migration and spawning (Rabour et al., 2003). Consequently, the reserve of SFAs gets depleted by high energy use and is replaced at a relatively slow rate.

The concentrations of individual MUFAs and total MUFAs were not significantly different ($p < 0.05$) between seasons (Table 2). Palmitoleic (16:1, n-7; 37.93 to 44.69% MUFAs) and oleic (18:1, n-9; 46.56 to 62.08% MUFAs) acids were the most abundant MUFAs. The observation of invariable amounts of MUFAs in Nile perch from different seasons is in agreement with other findings. Huynh et al. (2007) found no significant difference in the concentration of MUFAs in spawning and non-spawning herring. These FAs, in general, play vital roles in energy metabolism. Henderson et al. (1984) demonstrated that MUFAs, mainly oleic, are required by the fish in large amounts for energy. The high level of MUFAs in fish lipids is mostly a result of the diet of the fish. However, the substantial amount of MUFAs during periods of reduced food intake has been attributed to their rapid seasonal accumulation (Osako et al., 2003).

Levels of total omega-3 FAs in oils from Nile perch belly flaps varied ($p < 0.05$) with capture season (Table 2). Omega-3 FAs were higher in Nile perch obtained during the wet season than during the dry season. The higher amounts of omega-3 FAs in Nile perch belly flaps during the wet season also coincided with spawning (Rabour et al., 2003). EFAs are needed

in substantial amounts for the development of gonads (Wu et al., 2002). Data on variations of PUFAs in herring oils have indicated a similar trend with the highest proportion occurring during spawning season (Huynh et al., 2007). DHA and EPA are obtained through dietary sources or may be synthesized to meet the immediate nutrient requirement (Moffat et al., 1993; Wu et al., 2002). Studies have demonstrated that DHA synthesis increases during reproduction, since it is a major component of cell membrane structure (Tocher & Sargent, 1984). Moreover, MUFAs are utilized in preference to DHA and EPA during reproduction for metabolic energy (Huynh et al., 2007). This conserves the DHA and EPA reserves making their proportions relatively high in fish lipids during spawning.

The concentration of linoleic acid (18:2, n-6), the most abundant omega-6 FA in Nile perch, was not significantly ($p < 0.05$) different between capture seasons. Similarly, omega-9 FAs, mainly oleic acid (18:1, n-9), did not show seasonal variation, and their concentrations remained in substantial levels (19.04 to 21.07% total FAs). Huynh et al. (2007) showed that omega-9 FAs are utilized for energy during spawning migration. This could explain the constant amounts of omega-9 FAs in Nile perch belly flap, since their amounts not only depend on diet but also on accumulation (Osako et al., 2003).



## Variation in Levels of Contaminants

Levels of chlorofenvinphos and organochlorine pesticides were not significantly different ($p < 0.05$) in the belly flap oils of Nile perch from Lake Victoria and Lake Albert (Table 3). Trace levels of chlorofenvinphos detected in belly flap oils is indicative of past use of the pesticide in the lake region. Studies by Kituyi and colleagues (1997) reported substantial use of chlorofenvinphos in the control of ticks in East Africa. Resistance of ticks to organochlorine pesticides still contributes to the importation and application of organophosphorus in the Lake Victoria region (Wasswa et al., 2004). Organochlorines are listed among the most imported and used pesticides in Uganda (Wasswa et al., 2004). This explains the significant levels of chlorofenvinphos and organochlorine pesticides in oils from Nile perch belly flaps. However, data is lacking on the distribution of organophosphorus and organochlorine pesticides in the Lake Albert and Lake Victoria environment.

Levels of lead (Pb) and cadmium (Cd) in Nile perch belly flaps varied significantly ($p < 0.05$) with capture site. Lead concentration was in the range 116 to 203 $\mu g \cdot kg^{-1}$, while Cd varied from not detected to 2.56 $\mu g \cdot kg^{-1}$. Belly flap oils of Nile perch from Lake Victoria contained a higher concentration of Pb but lower level of Cd than that of Nile perch from Lake Albert (Table 4). Industrial effluents and combustion of lead-containing fuels contribute greatly to Pb concentration in Lake Victoria (Muwanga et al., 2006). The low amount of Pb in Lake Albert Nile perch is probably because the

**TABLE 3** Variation in Trace Levels ($\mu g \cdot kg^{-1}$) of Organic Pesticides in Oils Extracted from Nile Perch Belly Flaps with Capture Site and Season

| | Concentration ($\mu g \cdot kg^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Lake Victoria Nile perch | | Lake Albert Nile perch | | |
| Pesticide residues | Wet season | Dry season | Wet season | Dry season | MRL* |
| Sampling period | | | | | |
| Total DDT | 59.63 ± 28.87 | 23.48 ± 2.89 | 29.58 ± 6.18 | 20.18 ± 6.98 | 5000 |
| O,P′-DDE | 1.07 ± 0.77 | 0.27 ± 0.21 | 0.94 ± 0.82 | 0.1 ± 0.06 | 5000 |
| P,P′-DDE | 45.10 ± 24.62 | 19.49 ± 3.54 | 20.71 ± 5.28 | 16.63 ± 5.88 | 5000 |
| O,P′-DDD | 2.06 ± 0.82 | 0.59 ± 0.16 | 0.84 ± 0.18 | 0.47 ± 0.10 | 5000 |
| P,P′-DDD | 1.59 ± 2.00 | 0.70 ± 0.26 | 0.78 ± 0.50 | 0.37 ± 0.09 | 5000 |
| O,P′-DDT | 5.63 ± 4.16 | 1.10 ± 1.22 | 1.38 ± 0.60 | 0.43 ± 0.28 | 5000 |
| P,P′-DDT | 4.18 ± 2.88 | 1.34 ± 0.55 | 4.93 ± 1.63 | 2.11 ± 1.68 | 5000 |
| Endosulfan | 8.73 ± 3.89 | 6.82 ± 5.74 | 7.86 ± 6.68 | 6.44 ± 5.48 | 10 |
| $\alpha$-HCH | ND** | 2.47 ± 0.64 | ND | 2.22 ± 2.10 | 200 |
| $\gamma$-HCH | 0.70 ± 0.10 | 1.05 ± 1.18 | 0.73 ± 0.12 | 1.90 ± 1.13 | 500 |
| $\beta$-HCH | 1.77 ± 2.29 | 0.29 ± 0.50 | 2.96 ± 2.40 | 1.89 ± 1.75 | 100 |
| Aldrin | 4.15 ± 6.47 | 0.28 ± 0.18 | 0.40 ± 0.16 | 0.21 ± 0.08 | 200 |
| Dieldrin | ND** | 1.67 ± 1.72 | 1.30 ± 0.98 | 2.07 ± 0.74 | 200 |
| Endrin | 3.17 ± 2.47 | 2.39 ± 0.27 | 2.53 ± 1.01 | 2.03 ± 0.81 | 10 |
| Heptachlor | 3.07 ± 3.32 | ND | ND | 0.22 ± 0.38 | 10 |
| Chlordane | 2.17 ± 1.80 | 0.25 ± 0.34 | 0.60 ± 0.79 | 0.31 ± 0.43 | 10 |
| HCB | 0.51 ± 0.35 | 0.28 ± 0.04 | 0.63 ± 0.57 | 0.14 ± 0.08 | 500 |
| Chlorofenvinphos | 4.33 ± 2.31 | 2.80 ± 1.47 | 5.37 ± 1.56 | 3.49 ± 1.01 | NS*** |

DDT: dichlorodiphenyltrichloroethane; DDD: dichlorodiphenyldichloroethane; DDE: dichlorodiphenylchloroethane; HCB: hexachlorobenzene; HCH: hexachlorocyclohexane; *MRL: German maximum residue level; **ND: not detected; ***NS: no standard.
Values in rows were not significantly different ($p < 0.05$).



**TABLE 4** Variation in Trace Levels ($\mu g \cdot kg^{-1}$) of Heavy Metals in Oils Extracted from Nile Perch Belly Flaps with Capture Site and Season

| Sampling period | Lake Victoria Nile perch | | Lake Albert Nile perch | | MRL |
|---|---|---|---|---|---|
| | Wet | Dry | Wet | Dry | |
| Arsenic | ND* | ND | ND | ND | NS** |
| Cadmium | ND | $0.64 \pm 0.62^{b}$ | ND | $2.56 \pm 1.62^{a}$ | 100 |
| Lead | $203.19 \pm 20.17^{a}$ | $181.84 \pm 25.45^{a}$ | $116.32 \pm 18.29^{b}$ | $125.11 \pm 12.34^{b}$ | 500 |
| Mercury | 3.97 ± 2.86 | ND | ND | ND | 500 |

MRL: German maximum residue level; *ND: not detected; **NS: no standard. Values in rows followed by a different superscript are significantly different ($p < 0.05$).

lake is located far from lead emission sites. The difference in amounts of Cd in Nile perch from Lake Albert and Lake Victoria could be attributed to natural deposition. Lake Victoria waters and sediments contain very low levels of Cd (Muwanga et al., 2006). Levels of mercury (Hg) and arsenic (As) in

oils from Nile perch belly flaps were below detection limits in fish obtained during the dry season.

Trace amounts of organochlorine and chlorofenvinphos pesticide residues in belly flap oils of Nile perch did not show significant differences between capture seasons (Table 3). The amounts of Hg (not detected to 3.97 $\mu g \cdot kg^{-1}$) detected in the oils during the wet season could have been a consequence of gold mining reported along Lake Victoria (Van Straaten, 2000). Levels of Pb in Nile perch belly flaps were not different ($p < 0.05$) between the seasons.

## CONCLUSION

Fatty fish from different waters may differ in chemical composition from those having an adequate food supply that provides high fatty material yield and essential nutrients. Fish belly flaps with high fatty material yield and vitamin A content are found during the non-spawning period of intensive feeding, which takes place in dry seasons for Nile perch. The belly flap oils from fish obtained during the wet season, the spawning period for Nile perch, provide a rich source of omega-3 fatty acids. In addition, fish from less contaminated waters may not show any significant variation in levels of contaminants with site as well as season. Nile perch obtained from waters with low contaminants and high food supply, therefore, provide raw materials for oil production with a high content of essential nutrients.

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