Chemical composition, minerals content and fatty acids profile of five freshwater fish species

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Abstract

This study evaluated the nutritional composition of five freshwater fish species (*Bagrus bajad*, *Lates niloticus* L., *Mormyrus casahive* L., *Oreochromis niloticus* L., *Synodontis schall*). *M. casahive* showed the highest dressing (72.89%) and fillet (86.41%) percentages. Remarkably, *M. casahive* had the lowest acid value (0.02 mg KOH/g) while the highest value was found in *L. niloticus* (0.12 mg KOH/g). Highest protein and ash contents were found in *O. niloticus*, *S. schall* and *L. niloticus* while the highest fat content was found in *M. casahive*. Potassium is the predominant mineral found in all fish species with *L. niloticus* exhibiting the highest value followed by *M. casahive*. Among the trace element, zinc was found in greater amount in all fish species except *B. bajad* where iron was present in high quantity. *M. casahive* has the highest saturated fatty acids (63.72%) followed by *B. bajad* (26.67%). Interestingly, *S. schall* and *O. niloticus* have high unsaturated fatty acids. The greatest eicosapentaenoic acid (EPA) content (9.99%) was found in *L. niloticus*. In conclusion, these fishes supply human with healthy and nutritious foods.

Keywords: Chemical composition; Dressing percentage; Freshwater fishes; Fatty acid profile; Mineral contents.

1. Introduction

Generally, fish has been an important source of foods for human since it is among good sources of protein, highly digestible and rich in unsaturated fatty acids. Moreover, it contains high amount of other nutrients such as minerals and essential amino acids for the development of functional and structural proteins (Mahboob *et al*., 2015). Increase in human population has led to increase in demand for alternative source of proteins and the gap in fish supplies and as human food are expected to be filled by aquaculture industries (Naylor *et al*., 2000). Moreover, in recent years, there is a high demand for foods that enhances health and well-being. Fish has a particular prominence in this respect since it is the major source of omega-3 polyunsaturated fatty acids in particular EPA and DHA. These fatty acids are of great importance due to their ability to reduce the risk of cardiovascular diseases such as hypertension, arthritis, cancer and inflammation (Mateos *et al*., 2011). However, there is a concern that same fish species from

different freshwater sources vary in their nutritional composition particularly fatty acid profiles, minerals, and protein contents and this was attributed to environmental factors like feeds, temperature, and salinity (Inhamuns & Franco, 2008). Assessing meat quality of fresh water fishes that are less frequently analyzed will be of great importance since it will provide valuable information in preserving the quality especially during postharvest processing and storage (Mohamed *et al*., 2010). Also, in order to assure that the fishes meet the requirements of food regulations and commercial specifications, measurement of some proximate profiles such as protein, lipids and moisture contents are often of importance.

The River Nile in Sudan is rich in fish biodiversity with approximately 128 species belonging to 27 families (Frans *et al*., 2009). In spite of high fish potentialities in Sudan, yet consumption of fish meat is still quite low compared to that of red meat and this may probably be due to poor postharvest processing and preservation. Also, in rural and urban regions of Sudan, fish is important in food security and poverty alleviation, however, there is not much information on the nutritive value of major fish species present in freshwater of River Nile in Sudan. Therefore, the present study evaluated the physicochemical properties, chemical composition, mineral contents, and fatty acids profile of five commercial fishes (*Bagrus bajad*, *Lates niloticus* L., *Mormyrus casahive* L., *Oreochromis niloticus* L., *Synodontis schall*) present in River Nile in Sudan.

2. Materials and method

2.1. Collection of samples

Five species of freshwater fish from River Nile commonly consumed in Sudan were used in this study. Families, genera, species as well as local and English names of these fishes are presented in Table 1. Fresh fish samples (4 kg each × 3 fishes) of the same freshness, catch period, weight (480-600 g/fish), and approximate length (25-30 cm/fish) were collected randomly from fishermen. The samples were then transported within 2-3 hours in ice boxes (4 °C) to the laboratories of Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum. All reagents used were of analytical grade and procured from Fisher Scientific Co. (Rochester, New York).

2.2. Sample preparation

Fish samples were thoroughly washed with clean water to remove all contaminants or unwanted particles and dirt, disemboweled and beheaded. The non-edible portions (offal, head, viscera, and scales) were removed and weighed to determine percentage of edible portion in each fish. Fish muscle was separated from the bones and the lean muscle remaining was chopped into pieces (0.25 cm) and the minced samples were analyzed.

2.3. Dressing percentage and fillet yield

The method of Clement and Lovell (1994) was used to determine the quality of fish species. The edible and inedible parts were estimated. Dressing and fillet yield percentages were then calculated as follows:

$$Dressing\ (\%) = \frac{Total\ body\ weight\ (g) - inedible\ parts\ weight\ (g)}{Total\ body\ weight\ (g)} \times 100$$

$$Fillet\ (\%) = \frac{Fillet\ weight\ (g)}{Carcas\ weight\ (g)} \times 100$$

2.4. pH determination

Exactly, 50 mL of distilled water was added to 10 g of fresh minced fish samples. The mixture was stirred well for about 5 min, and contents were then allowed to settle. The pH of the mixture was recorded using HI 255 combined pH meter.

Table 1. The types of the fish species used in this study

Family	*Genus*	*Species*	*Local name*	*English name*
Bagridae	Bagrus	*Bagrus bajad*	Bayad	Forskal's catfish
Centropomidae	Lates	*Lates niloticus (L.)*	Ijeel	Nile Perch
Mormyridae	Morymyrus	*Mormyrus casahive (L.)*	Khashm elbanat	Elephant Snout
Cichlidae	Tilapia	*Oreochromis niloticus (L.)*	Bulti	Perch
Mochokidae	Synodontis	*Synodontis schall*	Gargur	Bolch-Schneider

2.5. Chemical composition

The chemical composition of fresh fishes was determined according to AOAC standard methods (AOAC, 2005).

2.6. Determination of mineral contents

The minerals (sodium, potassium, iron, zinc, copper, and calcium) were extracted using dry ashing method (AOAC, 2005). Samples were ashed at 550°C to a constant weight, dissolved with distilled water and few drops of concentrated HCl were added. Sodium and potassium elements were determined using a flame photometer (Model PFP7, Jenway, UK). Calcium, Fe, Zn and Cu were calculated by Atomic Absorption Spectrophotometer (Pekin-Elmar, 3110, USA).

2.7. Determination of acid value

Acid value was analyzed according to AOAC method (AOAC, 2005). One ml of oil or fat extracted from fish samples was transferred into a glass vial and dissolved in mixture of 100 mL of ethanol and diethyl ether (1: 1; v/v), heated gently and titrated with shaking against 0.1M KOH in ethanol, accurately standardized with 0.1 M HCl, using 1% phenolphthalein in 95% C_2H_5OH as indicator (5 drops). The end point was recorded when a faint pink color persist for ten seconds. The results were expressed as mg KOH/g. The equation below was used to calculate the acid value.

$$Acid\ value = \frac{(A - B) \times N \times 56.1}{W}$$

Where: A; volume (mL) of standard KOH used in titrating the sample, B; volume (mL) of standard KOH used in titrating the blank, N; normality of standard KOH, 56.1; molecular weight of KOH, and W; weight of the sample.

2.8. Fatty acids analysis

Methyl esters of fatty acids were analyzed using gas Chromatography apparatus (Shimadzu GC 2010, Kyoto, Japan) provided with FID and coupled with shimadzue C-R3A computerized integrator. A fused silica capillary column DB-1 (30 m×0.2 mm ID×0.2 5µm film thicknesses) was used. Nitrogen air was used as the carrier gas and set at flow rate of 50 ml/min. The initial temperature of the column was set and held at 150 °C for 1 min. The temperature was then raised at 2 °C/min to 188 °C and increased at the same rate to 300 °C. The peaks were identified by using an external 38 mixed FAME standard (Supelco, USA). Identification of fatty acids were done by matching their peaks with the relevant peak areas of corresponding standard fatty acids. The Concentration of individual fatty acid was calculated and expressed as a percentage of the total fatty acids.

2.9. Statistical analysis

Data were analyzed using the Software of the Statistical Analysis System (SAS). Experiments were carried out in triplicates. The data were assigned in Completely Randomized Design (CDR) and subjected to a one-way analysis of variance (ANOVA). Mean separation was done using Duncan Multiple Range Test (DMRT). The significance level was set at the probability level of ($P \leq 0.05$). HJ-biplot multivariate analysis was carried out using MULTBIPLOT software (Vicente-Villardón, 2010).

3. Results and discussion

3.1. Dressing and fillet percentages, pH, and acid value

Dressing and fillet percentages of the five fish species are presented in Table 2. The dressing percentage of fish is ranged from 47.9 to 72.89%. *M. casahive* showed significantly ($p \leq 0.05$) highest dressing percentage (72.89%) followed by *B. bajad* (70.9%) while the lowest value was found in *O. niloticus* (47.49%). The differences in the dressing percentage might be due to the differences in fish body size and morphology. The high dressing percentage (more than 50%) exhibited by the species means that less than half of the flesh is available for consumption, which might reduce their economic values. The inedible parts of fish such as bones and scales can be considered as industrial by-products and may be utilized in the production of fish meals. The nutritional profile of the sectional parts (head, tail, bone, viscera and skin regions) may be of importance in evaluating the nutrient content of the fish. *Mormyrus casahive* and *B*. *bajad* showed the highest fillet percentages (86.41% and 82.41%, respectively). This was followed by that of *L*. *niloticus* (70.2%) which was significantly ($p \leq 0.05$) higher than that of *O*. *niloticus* (55.56%) and *S*. *schall* (65.46%). Highly positive correlation ($r^2 = 0.984$, $P \leq 0.001$) was observed between dressing and fillet percentages indicating that fish with high dressing percentage will give higher fillet percentages. Variations in the flesh yield among the investigated species might be due to differences in genetic makeup and morphology of fish as well as the feed and water quality that plays a vital role in the chemical composition and growth of fish. The results obtained in this study agree with those reported in fish species collected from various water resources (El-Zaeem *et al*., 2012). The high fillet yield found in the fishes could be utilized in the setting up of cottage industries for the production of fish fillets, mince, sausage and nuggets. The utilization channels of these fish species may further enhance the distribution of commercially exploitable species of fresh water fishes.

Table 2. Dressing and Fillet percentages of Fresh water Fish

Species	Dressing	Fillet	pH	Acid value
Bulti (*O*. *niloticus*)	47.49^{e}±1.09	55.65^{e}±1.10	5.74^{e}±0.00	0.04^{b}±0.005
Gargour (*S*. *schall*)	51.30^{d}±0.76	65.46^{d} ± 0.67	6.49^{a}±0.03	0.05^{b}±0.005
K. elbanat *(M*. *casahive)*	72.89^{a} ±1.31	86.41^{a}± 1.05	5.81^{c}±0.03	0.02^{b}±0.002
Ijeel (*L*. *niloticus*)	56.96^{c}±1.16	70.20^{c}± 1.30	5.79^{d}±0.02	0.12^{a}±0.01
Bayad (*B. bajad*)	70.91^{b}± 0.25	82.41^{b} ± 1.37	6.24^{b}±0.01	0.04^{b}±0.003

Means (n=3) not sharing a common letter in a column are significantly ($P \leq 0.05$) different

The pH of fish flesh and gills has a great impact on its freshness because it affects bacterial growth. As shown in Table 2, the pH of the five fish species ranged from 5.74 to 6.49 with *S*. *schall* and *O*. *niloticus* species exhibiting the highest and lowest values, respectively. These values were lower than the values reported by Elhami (2011) for *L. niloticus* (6.75) and *M. casahive* (6.89) collected from River Nile. These variations may be due to differences in location, season, period of catch and handling time and process of fish samples, and analysis methods. Generally, fish products are acceptable up to a pH of 6.8 and the low pH found in these five fish species may reduce rate of microbial spoilage.

The acid value of the investigated fish species were found to range from 0.02 to 0.12 mg KOH/g (Table 2). *B. bajad* and *O. niloticus* showed comparable acid values of 0.04 mg KOH/g, which were significantly ($p \leq 0.05$) matched up to the value of 0.05 mg KOH/g recorded for *S. schall*. However, *M. casahive* demonstrated significantly ($p \leq 0.05$) the lowest acid value (0.02 mg KOH/g). Present results were markedly lower than the range of 5.03 to 8.40 mg KOH/g given by Abdulkadir *et al*. (2010) for five different fish species. The low acid values of fish oil reported here can be due to the differences in the kind and amount of lipids fish species and their habitats (Haliloglu *et al*., 2004).

3.2. Chemical composition

Table 3 shows the chemical composition of the five fish species. *B. bajad* has the highest moisture content and it was significantly different from other species. This was followed by *O. niloticus* and *L. niloticus* with similar values while the least moisture content was recorded in *M. casahive*. These values were consistent with those of

same fish species from River Nile reported in a previous study (Mohamed *et al*., 2010). In general, the major composition of fish tissues is water (Fafioye *et al*., 2008), and accordingly, fish species of this study could be classified as highly moist food due to its high moisture content, and therefore an appropriate technique for preservation is needed immediately after harvesting process. The high moisture content of the fish fillet would increase the deterioration level of fish during storage due to increased activity of the microorganisms associated with high moisture content (Love, 1980), thus *M. casahive* could be less liable to microbial deterioration as compared to other species.

Table 3. Approximate composition (g/100 g FW) of fish species

Fish species	Moisture	Protein	Fat	Ash
Bulti (*O. niloticus*)	74.30^{b}±0.17	22.90^{a}±0.05	1.44^{d}±0.04	1.42^{a}±0.04
Gargour (*S. schall*)	73.89^{c}±0.07	23.60^{a}±0.02	1.53^{c}±0.01	1.42^{a}±0.01
K. elbanat *(M. casahive)*	72.96^{d}±0.28	19.94^{b}±0.20	6.06^{a}±0.02	1.08^{b}±0.01
Ijeel (*L. niloticus*)	74.20^{b}±0.01	23.03^{a}±0.20	0.98^{e}±0.03	1.38^{a}±0.05
Bayad (*B. bajad*)	79.10^{a}±0.04	17.22^{c}±0.01	2.23^{b}±0.020	1.03^{b}±0.01

Means (n=3) not sharing a common letter in a column are significantly ($P \leq 0.05$) different.

The *L. niloticus*, *S. schall* and *O. niloticus* exhibited significantly higher protein content than that of *M. casahive* and *B. bajad*. Protein content of *L. niloticus* was higher than the value of 19.3% reported for the same species from Lake Victoria (Okeyo *et al*., 2009). However, the amount of protein found in *S. schall* is lower than that noticed in *S. schall* (43.2%) as reported by Fafioye *et al*. (2008). The differences in protein content may be due to differences in type of species, geographical area, seasonality, fish size, age, and the nature of feed as well as consumption and absorption capacities and ability to metabolize their feeds' essential nutrients. The fish species reported in this study are rich in protein, which could be used as a substitute to animal protein.

The fat contents of the fish species ranged from 0.98 – 6.06 g/100 g FW. Among the species, *M. casahive* has maximum fat content (6.06 g/100 g FW) and this was followed by *B. bajad* (2.23 g/100 g FW) while the lowest value was found in *L. niloticus* (0.98 g/100 g FW). The fat range found in this study was lower than that reported by Rosli *et al*. (2012) for three fresh water fishes. Fish can be categorized on the basis of their fat levels into lean fish (less than 5% fat), medium fat-fish (5-10% fat) and fatty fish (more than 10% fat) (Osman *et al*., 2007). Accordingly, *M. casahive* can be considered as a medium fat fish, while the remaining four species probably belong to the lean fish category. Generally, fish with high fat content has lesser slaughter yield due to an increase in weight of viscera in relation to body weight (Adeyeye, & Adamu, 2005). Also high rate of feeding and fish size may cause increased adipose deposition and lower water level in the fish body. Thus, fish with high lipid has more protein and low water contents as compared with low lipid fishes, since protein form the largest quantity of dry matter in fish. This also approved by high positive correlation (r^2= 0.958; $p \leq 0.01$) between protein and ash content observed in the current study. Similarly, Mahboob *et al*. (2015) observed positive correlation between protein and ash contents of farmed and wild fresh water fish (*Cyprinus carpio*).

Three of the fish species, *O. niloticus*, *S. schall* and *L. niloticus* have ash contents that were similar and significantly higher than that of *M. casahive* and *B. bajad*. The range of ash content of fish fillets in this study was in line with the results of a previous study (Adeniyi *et al*., 2012). In the examined fishes, the frequency in which these components are available in the water body as well as the capacity of the fish to absorb and change the necessary nutrients from the diet or the water bodies where they live resulted in the inconsistencies recorded in the ash values as well as in the concentrations of the other nutritional constituents (Martino *et al*., 2002). Furthermore, ash in the muscles of fish declines steadily during the starvation of non-fatty fish once the moisture content has increased above critical value (Devi, & Sarojnalini, 2012).

3.3. Mineral content

Table 4 shows the mineral contents of the fish species from Nile River. Potassium is the major mineral contents found in all fish species and it ranged from 333.3 – 428.3 mg/100g, with *L. niloticus* and *O. niloticus* having the highest and lowest values, respectively. This value falls within the range of 300-458 mg/100g reported by

Mohamed et al. (2010) but higher than the value (8.90-10.10 mg/100 g) reported in *Tilapia mosambis* fish (Adefemi, 2011). Potassium is known to be toxic to fish and its bioaccumulation could be very beneficial to human since it is an essential mineral in human nutrition (Love, 1980). Sodium ranked second among the major mineral elements analyzed. Its level in the muscles of examined species ranged from 78.3 – 206.6 mg/100 g and this was higher than the range of 59.2 - 75.12 mg/kg reported by Adeniyi *et al*. (2012). Also, *L. niloticus* have significantly highest sodium contents and this was followed by *B. bajad* while *O. niloticus* had the least value. Sodium content of *O. niloticus* is lower than the value of 0.80% given by Fawole *et al*. (2007) for the same species from Nigeria. Generally freshwater fish are somewhat lower in sodium than salt water fish. Some species from different areas shows differences in sodium which may be associated with life cycle, pre-or post-spawning (Love, 1980). The calcium content was found to be in the range of 6.05 – 13.46 mg/100 g, which was in consistency with the results of Adefemi (2011) who reported range from 6.2 – 10.10 mg/100 g in *Tilapia mosambis* fish. The levels of calcium in the fish species follows similar trend as that of potassium and sodium content with *L. niloticus* and *O. niloticus* having significantly highest and lowest values, respectively. Calcium content of *O. niloticus* is lower than the result given by Fawole *et al*. (2007) who reported 0.2% calcium for the same species from Nigeria. Also, Kabahenda *et al*. (2011) reported higher calcium content (134.2 mg/100g) for *L. niloticus*. Zinc is the most abundant minor minerals present in all fish species except *B. bajad* with a range from 0.98 - 2.59 mg/100 g. *S. schall* has significantly highest Zn content and this was followed by *O. niloticus* and *M. casahive* while the least value was found in *B. bajad*. Kabahenda *et al*. (2011) reported lower zinc content (0.72 mg/100g dry weight) for *L. niloticus*, whereas Fawole *et al*. (2007) reported higher (0. 43%) Zn content for *O. niloticus* from Nigeria. Strong positive correlation (r^2= 0.933; p ≤ 0.01) was observed between Zn and ω-6: ω-3 fatty acids, whereas it showed negative correlation (r^2= -0.878; p ≤ 0.05) with ω-3 fatty acids. The amount of Cu in the fish species ranged from 0.46 – 0.64 mg/100g. No significant difference was found in the Cu content of all the fish species except that of *S. schall* where the lowest value was recorded. Fawole *et al*. (2007) reported higher Cu value (0.02%) for *O. niloticus* from Nigeria. In this study, the copper content for all studied fish species is higher than the limit (0.3 mg/100g) that set by FAO/WHO (2001) for fish and fishery products. The high concentrations of copper could be attributed to natural or anthropogenic metal sources affecting the location of the studied fish (Irwandi, & Farida, 2009). These differences of copper in different parts of fish can be due to the variation in the environment where the fish lives in, where several a crucial factor such as environmental temperature is applied. Iron content of all the fish species ranged from 0.41 – 3.45 mg/100 g, which is lower than the range given by Adeniyi *et al*. (2012). Iron is the most abundant minor minerals found in *B. bajad* (3.45 mg/100 g) and this is significantly higher than that recorded in other fish species, with *M. casahive* exhibiting the lowest value (0.41 mg/100 g). Fe showed strong positive correlation (r^2= 0.969; p ≤ 0.01) with moisture suggesting that fish with higher moisture might have higher Fe in its meat compared to those with low moisture content. Current results for *L. niloticus* and *O. niloticus* were considerably lower compared to the values of 1.06 mg/100g dry weight and 0.1 formerly reported by Kabahenda *et al*. (2011) and Fawole *et al*. (2007), respectively for the same two species from different area. The variation between these studies could be due to the differences in geographical and environmental conditions among various other factors.

Table 4. Mineral contents (mg/ 100 g) of fresh water fish from Nile River

Fish species	K	Na	Ca	Zn	Cu	Fe
Bulti (*O. niloticus*)	333.3^{e}±0.04	78.3^{e}±0.20	6.05^{c}±0.80	1.57^{bc}±0.06	0.62^{a}±0.08	0.7^{c}±0.05
Gargour (*S. schall*)	373.3^{c}±0.02	90.0^{d}± 2.00	10.40^{b}±0.40	2.59^{a}±0.19	0.46^{c}±0.01	1.19^{b}±0.20
K. elbanat (*M. casahive*)	401.7^{b}±0.02	96.6^{c}±0.10	6.87^{c}±1.22	1.42^{bc}±0.10	0.64^{a}±0.07	0.41^{e}±0.02
Ijeel (*L. niloticus*)	428.3^{a}±0.86	206.6^{a}±3.00	13.46^{a}±1.06	1.31^{c}±0.007	0.63^{a}±0.03	0.59^{d}±0.07
Bayad (*B. bajad*)	368.3^{d}±0.66	98.3^{b}±1.00	13.20^{a}±0.50	0.98^{d}±0.05	0.58^{ab}±0.03	3.45^{a}±0.27

Means (n=3) not sharing a common letter in a column are significantly (P ≤ 0.05) different.

3.4. Fatty acid composition

The fatty acid composition of fresh water fish species collected from Nile River is shown in Table 5. The result showed that there is variation in saturated fatty acids (SFA) of the fish species. *M. casahive* had the highest amount of SFA while *S. schall* had the lowest value. Butyric acid (C4:0) was found to be the predominant SFA in *M. casahive*, *L. niloticus* and *B. bajad* with the highest values observed in *M. casahive* and the least value in *S. schall*. However, *O. niloticus* and *S. schall* had stearic acid (C18:0) as the most abundant SFA. With exception to *S. schall*,

Table 5. Fatty acid composition of fresh water fish species

Fatty acids (% of total fatty acid)	Bulti (*O. niloticus*)	Gargour (*S. schall*)	K. elbanat (*M. casahive*)	Ijeel (*L. niloticus*)	Bayad (*B. bajad*)
SFA					
Butyric (C4:0)	3.31^{c}±0.61	1.35^{d}±0.29	46.36^{a}±0.13	19.55^{b}±0.73	12.47^{b}±0.47
Caproic (C6:0)	nd	nd	0.50^{b} ± 0.03	1.10^{a}±0.07	nd
Undecanoic (C11:0)	1.51^{a}±0.07	0.06^{d}±0.00	1.46^{a}±0.05	1.38^{b}±0.04	1.13^{c}±0.00
Luaric (C12:0)	1.12^{a}±0.04	nd	0.13^{c}±0.14	0.42^{b}±0.11	1.13^{a}±0.04
Tridecanoic (C13:0)	0.78^{d}±0.07	0.03^{e}±0.01	1.36^{a}±0.13	0.97^{c}±0.01	1.14^{b}±0.01
Myristic (C14:0)	1.14^{c}±0.01	1.24^{b}±0.01	0.74^{d}±0.09	0.69^{d}±0.01	1.53^{a}±0.05
Pentadecanoic (C15:0)	0.35^{b}±0.05	0.27^{c}±0.01	0.22^{d}±0.02	nd	1.38^{a}±0.05
Palmitic (C16:0)	4.05^{b}±0.05	0.25^{d}±0.00	4.78^{b}±0.21	6.83^{a}±0.20	3.49^{c}±0.03
Heptadecanoic (C17:0)	0.55^{a}±0.03	0.30^{c}±0.03	0.98 ^{a}±0.02	0.33^{c}±0.00	nd
Stearic (C18:0)	4.50^{a}±0.11	4.57^{a}±0.11	4.10^{a}±0.33	2.66^{b}±0.00	1.38^{c}±0.17
Arachidic (C20:0)	0.79^{c}±0.01	0.11^{d}±0.01	0.28^{d}±0.18	1.09^{b}±0.02	1.60^{a}±0.01
Heneicosanoic (C21:0)	1.11^{d}±0.04	0.09^{e}±0.00	1.42^{c}±0.04	3.29^{a}±0.25	2.90^{b}±0.06
Tricosanoic (C23:0)	0.28^{b}±0.00	0.27^{b}±0.02	0.50^{a}±0.01	0.11^{c}±0.01	nd
∑ SFA	**19.49^{d}±0.52**	**8.54^{e}±0.10**	**62.83^{a}±2.44**	**38.42^{b}±1.67**	**28.15^{c}±1.01**
MUFA					
Myristoleic (C14:1 n-5)	4.34^{a}±0.10	3.89^{b}±0.01	2.55^{c}±0.02	0.22^{e}±0.05	1.47^{d}±0.00
Cis-10-pentadecenoic (C15:1 n-5)	3.14^{a}±0.01	0.33^{d}±0.14	1.28^{c}±0.01	2.02^{b}±0.16	3.19^{a}±0.07
Palmetoleic (C16:1 n-7)	3.58^{a}±0.33	0.44^{d}±0.01	2.75^{b}±0.01	1.02^{c}±0.04	3.9^{a}±0.08
Cis-10 heptadecenoic (17:1 n-7)	40.01^{a}±0.69	7.92^{d}±0.91	5.40^{e}±0.14	22.85^{c}±0.08	25.27^{b}±0.24
Oleic (C18:1n-9)	14.52^{b}±0.15	54.2^{a}±0.36	1.57^{e}± 0.10	5.37^{c}±0.14	4.81^{d}±0.18
Elaidic (C18:1n-9t)	0.46^{b}±0.04	0.20^{d}±0.00	0.20^{d}±0.00	0.29^{c}±0.03	0.72^{a}±0.01
Cis-11- eicosenoic (C20:1n9)	0.40^{d}±0.04	0.16^{e}±0.00	1.46^{b}±0.01	2.18^{a}±0.09	0.95^{c}±0.03
∑ MUFA	**66.45^{a}±2.34**	**67.14^{a}±1.88**	**15.21^{d}±0.89**	**33.96^{c}±0.97**	**40.31^{b}±1.33**
PUFA					
Linolelaidic (C18:2 n-6t)	0.65^{e}±0.02	18.02^{a}±0.07	8.23^{d}±0.05	9.21^{c}±0.00	12.15^{b}±0.03
Linoleic (C18:2 n-6)	0.69^{b}±0.03	0.41^{c}±0.01	0.71^{b}±0.06	0.24^{d}±0.01	3.39^{a}±0.12
Gamma-Linolenic (C18:3 n-6)	0.79^{c}±0.08	0.85^{c}±0.03	1.29^{b}±0.01	1.82^{a}±0.01	0.62^{d}±0.00
Arachidonic (C20:4 n-6)	0.49^{d}±0.02	0.30^{e}±0.00	2.23^{a}±0.13	1.05^{c}±0.04	1.58^{b}±0.17
Cis-11 14-eicosadienoic (20:2 n-6)	1.35^{a}±0.07	0.44^{d}±0.01	1.04^{c}±0.05	nd	1.13^{b}±0.03
Cis-8,11,14 eicosatrienoic (20:3 n-6)	4.01^{b}±0.25	0.52^{e}±0.05	3.28^{d}±0.16	3.59^{c}±0.01	4.59^{a}±0.06
EPA (20:5 n-3)	6.18^{c}±0.20	0.27^{e}±0.03	5.03^{d}±0.05	9.99^{a}±0.90	8.11^{b}±0.10
Cis-13,16-docosadienoic (22:2 n-6)	nd	3.59^{a}±0.15	0.13^{c}±0.02	1.72^{b}±0.03	nd
∑ PUFA	**14.16^{e}±0.66**	**24.4^{c}±0.54**	**21.94^{d}±0.22**	**27.62^{b}±0.54**	**31.57^{a}±1.06**
∑UFA	**80.61^{b}±2.97**	**91.54^{a}±4.89**	**37.15^{e}±2.07**	**61.57^{d}±4.64**	**71.88^{c}±3.15**
PUFA/SFA	**0.73^{c}±0.08**	**2.86^{a}±0.02**	**0.35^{d}±0.05**	**0.72^{c}±0.04**	**1.12 ^{b}±0.09**
MUFA/SFA	**3.41^{b}±0.22**	**7.86^{a}±0.77**	**0.24^{e}±0.04**	**0.88^{d}±0.08**	**1.43^{c}±0.07**
UFA/SFA	**4.14^{b}±0.76**	**10.72^{a}±0.23**	**0.59^{e}±0.08**	**1.60^{d}±0.44**	**2.55^{c}±0.10**
Σ ω-3	**6.18^{c}±0.07**	**0.27^{e}±0.02**	**5.03^{d}±0.21**	**9.99^{a}±0.13**	**8.11^{b}±0.54**
Σ ω-6	**7.98^{d}±0.57**	**24.13^{a}±1.43**	**16.91^{c}±0.22**	**17.63^{b}±0.09**	**23.46^{a}±1.01**
ω-3:ω-6	**0.77^{a}±0.07**	**0.01^{d}±0.00**	**0.30^{c}±0.02**	**0.57^{b}±0.04**	**0.35^{c}±0.08**
ω-6:ω-3	**1.29^{e}±0.08**	**89.37^{a}±4.50**	**3.36^{b}±0.05**	**1.76^{d}±0.07**	**2.55^{c}±0.03**

Means (n=3) not sharing a common letter in a row are significantly (P ≤ 0.05) different

palmitic acid (C16:0) represent the second most abundant SFA in all species. Our findings agree with previous report where butyric acid was found to be the major SFA in some important freshwater fishes from Mediterranean, Aegean and Black sea (Alasalvar *et al*., 2002). In addition, palmitic and stearic acids were also reported as the major SFAs in the fillets of Chub mackerel and Peruvian morwong (Rincon-Cervera *et al*., 2019). Lean meat fishes of high fat content show high concentration of individual saturated fatty acids. A positive correlation was found between total fat and SFAs (r^2 = 0.867; p ≤ 0.05) mainly butyric acid, myrsitic acid and arachidic acid. It could be noticed that the SFA level increased with increase in fat content as observed in samples like *M. casahive*. With the exception of *M. casahive*, all fish species exhibited higher unsaturated fatty acids (UFA) than SFA (Table 5). Greatest amount of UFA was found in *S. schall* (91.54%) followed by *O. niloticus* (80.61%), and *B. bajad* (71.88%), while *M. casahive* (37.15%) had the

lowest value ($P \leq 0.05$). Similarly, Xu et al. (2018) reported that raw and fermented fish contained higher UFA than SFA. Among the monounsaturated fatty acids (MUFA) identified, oleic acid (C18:1n-9) was found to be predominant in *S. schall* while in other fish species cis-10 heptadecenoic (17:1 n-7) was found as a major MUFA with the highest value being observed in *O. niloticus*. EPA was also observed as the dominant PUFA in anchovy (*Engraulis encrasicolus*) fish caught from Turkish Black Sea (Tufan *et al*., 2011). The high oleic acid found in this study agrees with those reported previously in various fish species (Mohamed *et al*., 2010; Rincon-Cervera *et al*., 2019; Xu *et al*., 2018). A positive correlation was observed between acid value and MUFAs, particularly oleic acid ($r^2 = 0.73$; $p \leq 0.05$) and this may be due to fat oxidation. The degree of unsaturation in freshwater fishes varies with season and it rises as the water temperature falls and vice versa (Ugoala *et al*., 2009). As temperature drops, the amount of unsaturation tends to increase for fish in order to maintain the fluidity of the membrane and overall flexibility of the body. However, at higher surrounding temperature, it is important that the phospholipids increase to contradict extra fluidity (Martino *et al*., 2002). Our findings showed that most of the studied freshwater fishes had lower PUFAs than MUFAs which may be due to the fact the fish feed mainly on vegetation and plant materials (Osman *et al*., 2007). Among PUFA, linolelaidic acid (C18:2 n-6t) was found as the major PUFA in *S. schall*, *M. casahive*, and *B. bajad*. However, higher amount of EPA (20: 5 n-3) was found in other fish samples with *L. niloticus* having the highest value (9.99%) followed by *B. bajad* (8.11%), and *L. niloticus* (6.18%), while *S. schall* had the least value of EPA ($p \leq 0.05$). According to Gigliotti *et al*. (2011), n3 PUFAs have several health benefits such as lowering the occurrence of cardiovascular disease. Humans obtained these n3 fatty acids mainly from diet since it cannot be synthesized in the body, and this makes them highly important (Mozaffarian *et al*., 2005). Among the fish species, *S. schall* had n6/n3 ratio of 89.37 which was extremely higher than the maximum recommended ratio of 4.0 (HMSO, 1994) indicating that consumption of such fish meat could promote cardiovascular diseases (Moreira *et al*., 2001). However, the n6/n3 ratio of all other species (1.29-3.36) was lower than the maximum recommended ratio suggesting good nutritional and health qualities of these freshwater fishes. It has been reported that low value of this n6/n3 fatty acid ration is important to lower plasma lipids and prevent the risk of coronary heart disease (Gökçe *et al*., 2004). It is well known that diets with high n3/n6 ratio could help in the protection against various chronic diseases (Moreira *et al*., 2001). Despite, the lower ratio (0.01-0.77) of n3/n6 of all studied species than the ratio (1:1) recommended for fish and fish oils (Osman *et al*., 2007), the ratio of PUFA/SFA of most studied species was higher than the minimum (0.45) recommended ratio (HMSO, 1994) suggesting good health benefits of these species. A great negative correlation ($r^2 = -1.0$; $p \leq 0.0001$) was observed between SFA and UFA suggesting that increase in one will be on the expenses of the other and this is very clear as *S. schall* has the highest and the lowest UFA and SFA, respectively. Overall, the fatty acid profile was varied among studied species and the variation could be attributed to the differences in the genetic makeup, natural diets, environmental conditions, and size, age, and reproductive status of fishes.

3.5. Multivariate analysis

The interrelationship between fish species and physicochemical properties was assessed by using HJ-biplot multivariate analysis algorism. Principal component analysis (PCA) indicated good contribution of PC1 (39.53%) and PC2 (25.42%) axes to the plotted components as they give a great percentage (>64%) of the total variability of the data (Fig. 1). In the biplot, acute angle (<90º) of the cosine between the vectors of the parameters indicate positive correlation, obtuse (>90º) or straight (180º) angles indicate negative correlation, and right (90º) angles indicate no correlation. The graph showed clear interrelations between fish species and their physicochemical properties. The first quartile (upper right quartile) showed the species *L. niloticus* and *M casahive* those characterized by their higher amounts of Na, Cu, ω-3, ω-3: ω-6, and SFA than other species. Additionally, acute cosine between Cu, Na, ω-3, ω-3: ω-6, and SFA indicated positive correlations between them. This group of parameters also correlated positively with K, fat, and acid value, while they showed negative correlations with UFA, MUFA, Zn, pH, ω-6, and ω-6: ω-3 and they have no correlations with ash and protein. The second quartile (upper left quartile) composed of the *O. niloticus* that characterized by its higher protein, ash, acid value than other species. Protein and ash showed strong positive correlation between them and they both correlated positively with acid value, MUFA, UFA, and Zn. These properties showed no correlations with Cu, and ω-6: ω-3, and negative correlations will all other parameters. The third quartile (lower right quartile) composed of the species *B. bajad* which has high dressing and fillet percentages, moisture, PUFA, Ca, and Fe. Strong positive correlation was observed between dressing and fillet percentages and they both correlated positively with fat, K, moisture, PUFA, Fe, and Ca and no or negative correlations with other parameters.

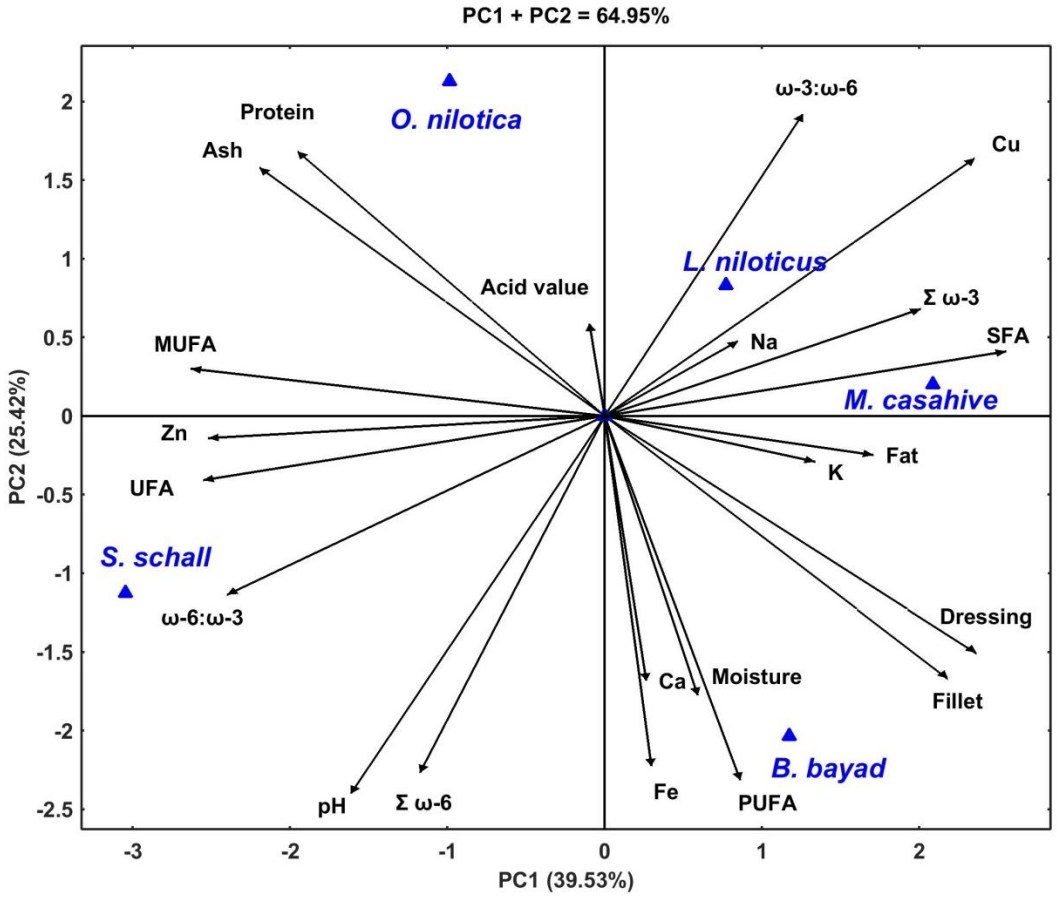

Figure 1. HJ-Biplot based on principal component analysis (PCA) for physicochemical properties of freshwater fish species from River Nile

The last quartile (lower left quartile) contained *S. schall* that characterized by higher ω-6: ω-3, pH, Zn, UFA, MUFA, and ω-6 compared to other species. These parameters are correlated positively with each other and negatively or no correlations with other properties. Overall, freshwater fishes from River Nile have diverse physicochemical qualities due to the variation in size, age, reproductive status and genetic makeup. With few exceptions, the studied freshwater species had good physicochemical qualities and consequently their consumption could provide human body with essential nutrients.

Conclusion

In conclusion, the five fish species are good source of protein, lipids, major minerals like potassium and sodium and trace elements such as zinc and iron. *M. casahive* had the highest dressing and fillet percentage. High unsaturated fatty acids were noticed in *S. schall* and *O. niloticus*. However, *L. niloticus* had the highest level of EPA. Thus, these fish species can provide healthy and nutritious foods required by human. The findings of this study could promote the consumption of freshwater fishes from River Nile at national and international levels.

Conflict of interest

The authors declare that they have no conflict of interest.

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