The chemical composition, fatty acid, amino acid profiles and mineral content of six fish species commercialized on the Wouri river coast in Cameroon

N. Tenyang[1]
H.M. Womeni[1*]
M. Linder[2]
B. Tiencheu[1]
P. Villeneuve[3]
F. Tchouanguep Mbiapo[1]

[1]University of Dschang
Faculty of Science
Department of Biochemistry
Dschang - Cameroon

[2]Laboratoire d'Ingénierie des Biomolécules
ENSAIA-INPL,
Vandoeuvre-les-Nancy Cedex
France

[3]Laboratoire de Lipotechnie,
CIRAD, UMR IATE
Montpellier Cedex 5 - France

*CORRESPONDING AUTHOR:
H.M. Womeni
University of Dschang
Faculty of Science
Department of Biochemistry
P.O. Box 67 Dschang, Cameroon
Tel.: (237) 99 97 84 49
e-mail address: womeni@yahoo.fr

The chemical composition and nutritional qualities of fats and proteins of six species of fish: Herring (*Clupea Harengus*), Belt (*Trichius Lepterus*), Catfish (*Arius Maculatus*), Red carp (*Cyprinus Carpio*), Disc (*Symphysadon Discus*) and Mullet (*Semotilus atromaculatus*) were investigated. The investigation showed that the chemical composition of fish is not the same in all species. The total protein content of the species is higher than 64.2%. The total lipid content was generally high, ranging from 8.9% to 23.0% and crude ash ranged from 10.7% to 19.4%. The most abundant fatty acids in all the species were saturated fatty acids (45.5 - 54.9%) and palmitic acid was the predominant saturated fatty acid in all these fish (C16:0: 26.7 - 34.0%). After saturated fatty acids, monounsaturated fatty acid was the second predominant fatty acid (26.7 - 36.9%) and oleic acid was the most abundant monounsaturated fatty acid in all these fish. Moreover, these fish contained reasonable amounts of essential polyunsaturated fatty acid (PUFA) such as docosahexaenoic, eicosapentaenoic, and arachidonic acids. The data revealed that all these fish were a good source of ω-3 PUFA ranging from 9.8% to 14.7%. Catfish contained the highest amounts of PUFA (20.9%). The lower level of ω-6 in these fish suggested that these fish especially Belt and Catfish, could be used as a source for a healthy diet for humans. All these fish contained 17 known amino acids, including all of the essential amino acids. The most abundant amino acids were glutamic acid (161.5 to 190.3 mg/g of protein), aspartic acid (108.6 to 148.2 mg/g of protein), glycine (52.7 to 70.8 mg/g of protein), arginine (42.5 to 57.6 mg/g of protein), proline (57.7 to 81.9 mg/g of protein), isoleucine (59.5 to 93.0 mg/g of protein), leucine (83.4 to 102.1 mg/g of protein), and lysine (60.5 to 74.7 mg/g of protein). The mineral analysis indicated high Ca, K and Mg content.

Keywords: Chemical composition, Fatty acids, Amino acid, Mineral content, Fresh marine fish, Wouri river coast

Composizione chimica, acidi grassi, profili di amminoacidi e contenuto di minerali di sei specie di pesci commercializzate sulla costa del fiume Wouri in Camerun

Sono state studiate la composizione chimica e le qualità nutrizionali dei grassi e delle proteine di sei specie di pesci: Aringa (*Clupea harengus*), Belt (*Trichius Lepterus*), Pesce gatto (*Ario maculatus*), Carpa comune (*Cyprinus Carpio*), Disc (*Discus Symphysadon*) e Mulet (*Semotilus atromaculatus*).
Dall'indagine è emerso che la composizione chimica dei pesci non era la stessa in tutte le specie.
Il contenuto totale di proteine era superiore al 64,2%. Il contenuto totale di lipidi era generalmente alto, e andava dall'8,9% al 23,0% e le ceneri grezze variavano dal 10,7% al 19,4%.

Gli acidi grassi presenti in maggiore quantità in tutte le specie erano gli acidi grassi saturi (45,5-54,9%) e l'acido palmitico era il predominante (26,7-34,0%). Dopo gli acidi grassi saturi, gli acidi grassi monoinsaturi erano i secondi acidi grassi predominanti (26,7-36,9%) e l'acido oleico era il maggiore acido grasso monoinsaturo contenuto nei pesci. Inoltre i pesci contenevano quantità ragionevoli di acidi grassi essenziali PUFA come gli acidi docosaesaenoico, eicosapentaenoico e arachidonico.
I dati hanno rivelato che i pesci erano una buona fonte di acidi grassi polinsaturi ω-3 che variava dal 9,8% al 14,7%.
Il pesce gatto conteneva la più alta quantità di PUFA (20,9%).
Il basso livello di ω-6 in questi pesci suggerisce che, in particolare il Belt e il pesce gatto, potrebbero essere utilizzati come sorgente per una dieta sana nell'alimentazione umana.
Tutti i pesci contenevano 17 amminoacidi conosciuti, tra cui gli amminoacidi essenziali.
Gli amminoacidi presenti in maggiore quantità erano l'acido glutammico (161,5-190,3 mg/g di proteina), l'acido aspartico (108,6-148,2 mg/g di proteina), la glicina (52,7-70,8 mg/g di proteina), l'arginina (42,5-57,6 mg/g di proteina), la prolina (57,7-81,9 mg/g di proteina), l'isoleucina (59,5-93,0 mg/g di proteina), la leucina (83,4 to 102,1 mg/g di proteine), e la lisina (60,5 a 74,7 mg/g di proteina). L'analisi minerale indicava un alto contenuto di calcio, potassio e magnesio.
Parole chiave: composizione chimica, acidi grassi, aminoacidi, minerali, pesce fresco di mare, fiume costiero Wouri

1. INTRODUCTION

Fish are the most numerous vertebrates with at least 20.000 known different species and more than half (58%) living in the marine environment [1]. Their proximate composition differs a little for the protein and minerals [2]. The lipid content on the other hand varies from one species to another and constitutes a base for the classification of fish into fat or lean fish [3]. Lean fish stores lipid only in the liver whereas fat fish keeps lipid in fat cells distributed in other tissues of the body [4]. In Cameroon, fish are the most important source of animal protein (44% and 7.6% of the total protein intake), vitamins and essentials minerals.
The consumption of fresh fish is high in urban and coastal areas. It is at a low level in rural areas, due to the low purchasing power and inadequacies in the distribution channel. Fish from the artisanal fishery is distributed along the coast and in the immediate vicinity of the production center. Douala consumes 30%, Kribi 20% and Limbé 15% of the fresh marine artisanal fisheries [5]. Fat fish present many advantages in the human diet and human health. These fish provide high quality lipids, which contain essential mono and polyunsaturated fatty acids of high biological and nutritional values. These lipids are easy to digest and play a preventive role against many cardiovascular diseases [6]. These lipids are also a rich energy source and have structural components necessary for reproductive development [7]. The lipids of fish are the only sources of certain PUFA that can regulate prostaglandin synthesis and hence induced wound healing [8; 9; 10]. The fat fish contain essential PUFA like eicosapentaenoic (EPA, C20:5n-3), docosahexaenoic (DHA, C22:6n-3), and arachidonic (C20:4n-6) acids which are not synthesized in the human body but their inclusion in human diets are essential [11; 12; 13]. They have valuable therapeutic properties and are used in the prevention and treatment of diseases such as cancer, coronary and heart disease [14; 15; 16; 17; 18]. Fish also contain significant amounts of essential amino acids, particularly lysine which is low in cereals. Fish protein can therefore be used to complement the amino acid pattern and overall protein quality of a mixed diet [19]. Certain amino acids like aspartic acid, glycine and glutamic acid are also known to play a key role in the process of wound healing [20].
In addition to fatty acids and amino acids, some fat fish also contain vitamins B and D and minerals. These nutrients perform all kinds of functions as structural components in tissues and cells, as activators or modulators of enzyme activity in metabolic pathways or as factors that control transcription. Deficiency in one of these essential nutrients has important implications for the pathogenesis of diseases, their morbidity and severity [21].
Fresh and marine water fish do not have the same composition and even within the same environment, the chemical composition varies [22]. Within the same species, there are some variations of the composition; this is due to season, geographical regions, age, maturity stage or even the feed of these fish [23]. The Wouri river, like any estuarine system has a variable salinity. The population explosion, the location of industries along the river Wouri are some factors responsible for the pollution of the river. For several years, the Wouri has become a “dumping ground” for industrial, household and even fecal waste [24]. The bacteriological analysis of water from the Wouri presented a serious bacterial and organic contamination especially at this port because of the pouring of untreated sewage into the river from Douala [25].
All these combine to make the Wouri river a particular ecosystem that will soon influence the chemical composition of the flora and fauna that exist. Hence the interest of this study seeks to determine the lipids composition, amino acids and mineral content of six fat fish commercialized on the Wouri river coast in order to determine their nutritional value. This study is likely to open new areas of research as the knowledge of chemical and fatty compositions of fish species is of fundamental importance in the application of different technological processes in fish preservation, processing and product development of high added values.

2. MATERIAL AND METHODS

2.1 WOURI LOCATION

The Wouri is a river that flows through the economic capital of Cameroon. It crosses Douala city in the Northwest region and flows along the direction from NE to SW (Fogwe & Tchotsoua, 2007). It is 160 km in length and the estuary is located in Douala. The Wouri estuary covers the port of Douala, located at 4°1’ North latitude and 9°45’ East longitude. This port is the gateway to the country and is the point of gravity for the whole economy of Cameroon. The Wouri is located 50 km from the sea and divides the city into two, connected by an old bridge which is over fifty years old. The Wouri river has shrunk over time. Two main activities are carried out on the Wouri river: economic trade and artisanal and industrial fisheries due to its open status to the sea and therefore the world [26]. The Youpowé market located along the Wouri river is renowned for its diversity of fish. This is a great center for the supply of fresh fish, also a transit center of smoked fish in the direction of other markets in Cameroon. Species that are marketed are mainly shrimps, pelagics of the Clupeidae family, and dermersales (bars, hunchbacks, pike).

2.2 COLLECTION OF SAMPLES

Six species of fishes from the Wouri river and sea were collected in the Wouri river coast in Douala, Cameroon and more specifically in the fishing areas located in Youpowé and Essingué (Naval Base).

The choice of species was made according to the size and texture. Once collected, they were immediately transported to the laboratory of Animal Biology and Biochemistry (LABPMAN) of the University of Dschang in ice boxes for identification and analyses. Fresh fish were washed with tap water several times to remove adhering blood and slime. In the biochemistry laboratory, the fish samples were separated and reduced to filet.

2.3 PROXIMATE COMPOSITION

2.3.1 Moisture content

Moisture content was determined in the fish muscle in duplicate according to methods 14004 AOAC [27], in an oven, at 105°C for 24 h.

2.3.2 Fat content

Total crude fat from muscle tissues was determined with the help of soxhlet apparatus using the non-polar organic solvent hexane according to methods 14006, AOAC [27].

2.3.3 Determination of crude protein

Nitrogen (N) contents of fish muscle samples were determined by the method 7015, AOAC [27]. The N content was multiplied with 6.25 to estimate the crude protein (CP) of these samples.

2.3.4 Ash content

Ash content determined by burning the organic components from the known weight of the homogenised dried fish muscle by using a furnace at 550°C according to methods 14009, AOAC [27].

2.3.5 Fatty acids composition

Lipids were extracted from the muscle tissues using the Bligh and Dyer [28] method, and fatty acid composition of the oil were investigated after conversion of their Fatty Acid Methyl esters (FAME) by using boron trifluoride-methanol method. The lipids were saponified and esterified for fatty acid analysis by the method of Metcalfe, Schmitz, and Pelka [29]. The fatty acid methyl esters (FAMEs) were analyzed on a Hewlett-Packard (HP) 5880 gas chromatograph (GC) with a flame ionisation detector (FID). The esters were separated on a 50 m × 0.20 mm i.d. wall-coated open tubular fused silica capillary column coated with Carbowax 20 M. Column injector and detector temperatures were 200 and 300°C, respectively. Carrier gas was helium; split ratio was 100:1. Identification was achieved by comparison to retention times of authentic standards, argentation TLC followed by GC of the bands separated by a degree of unsaturation, and mass spectrometry.

2.3.6 Amino acid analysis

The PICO TAG method with a modification was employed for determining the amino acid profile of the sample [30]. The amino acids were determined from standard curves based on peak area measurements. Five-point standard curves were made for all analyzed amino acids using reference materials. In addition, intraday variability (R.S.D.) and spike recovery studies were performed. Thirty milligrams of fish powder were hydrolyzed in a vacuum-sealed ampoule with 6M hydrochloric acid at 150°C for 1h. Ten milliliters of internal standard (α-amino butyl acid) were added to the mixture. After derivatisation, 100 mL PICO TAG diluent were added and mixed; 100 mL samples were then injected into the HPLC and analyzed with Waters PICO TAG amino acid analyzer. Tryptophan was not determined.

2.3.7 Mineral content

The mineral content of all fish samples was determined by the acid digestion method involving microwave technology (CEM microwave, MDS-2000, CEM corp., Mattews, NC). A 0.5 g fish sample was placed in a vessel, and 6 ml of HNO3 was added. The sealed vessel was heated until digestion had been completed, after what the sample was cooled for 5 min. The inductively coupled argon plasma (ICAP) machine was used to analyze the mineral content.

3. RESULTS AND DISCUSSION

3.1 PROXIMATE COMPOSITION

Scientific names, common names and chemical composition of six species of fish commercialized on the Wouri river coast in Douala, Cameroon are presented in Table I.

Table I - Scientific names and chemical composition of six species fishes of the Wouri river coast in Douala, Cameroon

Common Name	Scientific name	Moisture (% WW)	Fat (% DW)	Crude Protein (% DW)	Ash (% DW)
Belt	*Trichius Lepturus*	75.88±0.55	20.89±1.05	67.55±0.42	10.65±0.13
Herring	*Clupea Harengus*	78.97±0.32	10.20±1.12	69.43±0.72	19.42±0.09
Catfish	*Arius Maculatus*	76.48±0.26	23.02±0.88	64.24±0.14	10.98±0.31
Disc	*Symphysadon Discus*	81.18±0.12	11.35±0.96	72.62±0.42	15.49±1.87
Red carp	*Cyprinus Carpio*	74.19±0.91	15.32±2.79	69.02±0.11	14.28±0.12
Mullet	*Semotilus Astromaculatus*	78.91±0.54	8.90±0.56	68.94±0.19	19.00±0.13

Values are mean ± SD of two separate determinations. DW, dry weight; WW, wet weight.

Water content of these fish varied from one species to another and ranged these from 74.19 to 81.18%. The higher water content is obtained from the Disc sample (*Symphysadon Discus*) (81.18±0.12%), followed by Herring (*Clupea Harengus*) (78.97±0.32%), Mullet (*Semotilus Atromaculatus*) (78.91±0.54%). The lower water content is obtained from Red carp (*Cyprinus Carpio*) (74.19±0.91%). The high water content of the Disc predisposed it the more to degradation reaction such as hydrolysis [31]. The total lipid content of the different fish species varied from one sample to another. They are generally high ranging from 8.90% to 23.02%. The highest fat content is obtained from the Catfish species (Arius Maculatus) (23.02±0.88% on dry matter) and the lovest fat content is obtained from the Mullet species (*Semotilus atromaculatus*) (8.90±0.56% on dry matter).

These fish are often classified on the basis of their fat content into fatty fish (fat more than 10% weight), and medium fat fish (fat 5-10%) [31; 33]. Based on this classification, fish species such as Herring (*Clupea harengus*), Belt (*Trichius lepterus*), Catfish (*Arius maculatus*), Red carp (*Cyprinus Carpio*) and Disc (*Discus symphysadon*) are fatty fish and Mullet (*Semotilus Atromaculatus*) is a medium fat fish. The considerable variation in the total fat contents of the fish muscles among the species is due to both the importance of fish muscle as a storage site and its ability to deposit fat, but also in the food of these species in their natural environment, the season, age or even maturity of the species [34; 35; 36].

The crude protein content of these samples of fish in this investigation varied from one fish to another. Catfish (*Arius maculatus*) had the lowest protein content (64.24±0.14) while Disc (*Discus symphysadon*) obtained the highest value of protein content (72.62±0.42). The protein content of the Herring (*Clupea harengus*) is higher than that obtained by Sathivel Subramanian et al. [37] (14.5±0.1). In the present investigation, crude proteins were much higher than the protein levels for Carp (16% wet weight; FAO, [38]) and Tilapia (50-55% dry muscle tissue; Onyeike et al. [39]). The protein content of these fish species shows that their consumption could help to prevent some problems due to protein deficiencies in the diet of people in developing countries.

Generally, fish are regarded as an important source of high quality animal protein and can be used to supplement of diet for people in developing countries [40]. Some of the fish, especially marine fish are sources of higher polyunsaturated fatty acids quality and are much more susceptible to alteration reactions during transformation. Knowledge of chemical composition of these fish can predict reactions that can occur in these samples during treatment.

The ash content for the different species of fish from the Wouri river coast varied from one species to another. It remained higher in Herring (Clupea harengus) (19.42±0.09) and lowest in the Belt (Trichius Lepterus) (10.65±0.13). The ash content of the Herring is higher than that found by Sathivel Subramaniam et al. [38] (3.0±0.2). The ash content obtained in this investigation is in the range of 9-22%, as found by Liceaga-Gesualdo and Li-Chan [41] on samples of fish. The high ash content of Herring and Mullet samples proves that these samples are much richer in minerals.

The considerable variation of moisture, ash, crude protein and total lipids content of six studied species of fish from the Wouri river coast presented in Table I were in line with the findings of other authors [42].

3.2 FATTY ACID COMPOSITION

The fatty acid composition (% of total fatty acid) of the six fish species is summarized in Table II. Table III summarizes the content of saturated, monounsaturated, polyunsaturated fatty acids and ω-3/ω-6 polyunsaturated fatty acids ratio.

In the present investigations, the fatty acid composition and content of fish oils of the Wouri river coast varied from one species to another. All these fish species have each 22 fatty acids. Their lipids muscle are mainly composed of saturated fatty acids (SFA: 46-55%). Myristic (C14:0), pentadecanoic (C15:0), palmitic (C16:0), heptadecanoic (C17:0), stearic (C18:0) and arachidic acid (C20:0) were the dominating saturated fatty acids in all the fish species. Palmitic acid (C16:0) alone accounts for more than 60% of total fatty acids. Herring (*Clupea harengus*) is recognized as a species which has a higher content of saturated fatty acids and palmitic acid particularly (55% and 34% respectively of total fatty acids). However, the Red carp (*Cyprinus carpio*) is a fish which has the lowest saturated fatty acids content (45.5% of total fatty acids). High levels of saturated fatty acids in these samples are in line with those obtained by Gutierrez and Silvia [43] in Brazil, and Gopa and Nair [44] in India on marine fish oils. These results are different when compared to an earlier study on fresh marine fish in Malaysia, where the concentrations of saturated fatty acid were low [45]. The monounsaturated fatty acid content of all these species (MUFA: 27-37%) are higher than those of polyunsaturated fatty acids (PUFA: 14-21%) (Table III). Oleic acid is the most abundant monounsaturated fatty acid in these fish species. This fatty acid has an external origin and reflects the type of food consumed by these species. Red carp (*Cyprinus carpio*) presented higher oleic acid content (21.8%) while Herring (*Clupea harengus*) presented the lower oleic acid content (9.7%). These fish species from the Wouri river coast are sources of polyunsaturated fatty acids of the family of ω-3 (Table III). These results agree with those found by Gunstone [46]; Steffens [47]. Amounts of PUFA, eicosapentenoic acid (C20:5 n-3) (EPA) varied from 3 to 4.7%. Mullet (*Semotilus atromaculatus*), Catfish (*Arius maculatus*) and Herring *(Clupea harengus*) are fish which are the richest in EPA (4.7%) and Belt (*Trichius*

Table II - Fatty acid composition of six fish species at the Wouri river coast

Fatty acids as % of total fatty acids	Belt	Herring	Mullet	Catfish	Red carp	Disc
12:0	0.1	0.1	0.1	0.2	0.2	0.1
14:0	9.2	13.6	11.3	6.41	2.6	4.3
15:0	0.4	0.4	1.8	1.50	1.0	0.9
16:0	29,4	34,0	32.3	26.73	27.2	29.3
16:1(n-7)	15.1	13.5	15.7	6.58	6.5	7.0
17:0	0.4	0.3	0.9	2.43	1.8	1.4
17:1	2.3	3.7	3.1	0.98	1.1	1.0
18:0	6.4	5.9	5.4	13.04	11.8	10.4
18:1(n-9)	13.4	9.7	9.8	12.18	21.8	20.8
18:1(n-7)	5.4	3.4	2.9	5.31	5.5	3.5
18:2(n-6)	1.7	1.4	1.3	1.82	3.9	1.3
18:3(n-3)	1.7	0.9	0.9	1.33	2.2	0.8
20:0	0.4	0.3	0.1	2.03	0.4	0.6
20:1(n-9)	0.6	1.1	0.2	1.00	1.3	0.8
20 :4(n-3)	0.3	0.1	0.3	0.21	0.3	0.3
20 :4(n-6)	1,8	1.9	2.6	2.92	3.2	2.6
20 :5(n-3) EPA	3.0	4.7	4.7	4.60	3.1	3.9
22:0	0.1	0.1	0.1	0.31	0.7	0.0
22:1	0.1	0.1	0.3	0.63	0.1	0.0
22:5(n-6)	0.7	0.6	0.9	1.41	0.6	1.1
22:5(n-3)	4.8	1.6	3.3	2.54	1.8	2.8
22:6(n-3) DHA	2.6	2.5	2.4	6.05	3.4	7.2

Table III - The saturated, polyunsaturated fatty acids, ω-3 and ω-6 polyunsaturated fatty acids (% total fatty acids) and ω-3: ω-6 ratios of fatty acids from fish oils.

∑	Belt	Herring	Mullet	Catfish	Red Carp	Disc
SFA	46.4	54.9	52.0	52.63	45.5	47.0
MUFA	36.9	31.5	32.0	26.70	36.3	33.1
ω-3 PUFA	12.4	9.8	11.6	14.73	10.8	15.0
ω -6 PUFA	4.2	3.9	4.8	6.15	7.7	5.0
PUFA	16.6	13.7	16.4	20.88	18.5	20.0
ω-3:ω-6	2.95	2.51	2.42	2.40	1.40	3.0

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PURA: polyunsaturated fatty acid

lepterus) has the lowest content in EPA (3%). The docosahexaenoic acid (C22:6 n-3) (DHA) content also varies from one species to another. This content is higher in the Disc sample (*Discus symphysadon*) (7%) and lower in the Herring (*Clupea harengus*) and Mullet (*Semotilus atromaculatus*) samples (2%). The most PUFA for Catfish, Red carp and Disc species, was docosahexaenoic acid (C22:6 n-3, DHA) followed by eicosapentaenoic acid (C20:5n-3, EPA). Kolakowska *et al*. [48] reported that DHA is usually more abundant than EPA. The high content of DHA in these samples can be due to the high content of phospholipids, which normally contain high amounts of polyunsaturated fatty acid. DHA and EPA acids have shown their worth in the prevention of coronary heart disease in humans [49]. Therefore, fish have been suggested as a key component for a healthy diet in humans [22]. All these fish species contained arachidonic acid (C20:4 n-6) in varying amounts. It is most represented in Red carp (*Cyprinus carpio*) with 3.2% of content and lower in the Belt (*Trichius lepterus*) and Herring (*Clupea harengus*) (1.8%). This fatty acid is a precursor for prostaglandin and thromboxane biosynthesis [50; 51]. Arachidonic acid can facilitate the blood clotting process and attach to endothelial cells during healing [22]. Although the level of arachidonic acid was high in these selected fish species, the inclusion of these fish in human diets might help in the wound healing process of the consumers.

Similarly, the linoleic acid (C18:2 ω-6) content varied from one species of fish to another. Its content is highest in Red carp (*Cyprinus Carpio*) (3.9%) and is recognized as a precursor of arachidonic acid. These two fatty acids play an important role in fertilization, implantation and fetal development and finally parturition [52]. Significant levels of EPA and DHA in fish species of this study indicated that these species can be used to supplement essential fatty acids in the human diet.

Polyunsaturated fatty acids of marine origin play an important role on human health. Indeed several studies reported that the ω-3 fatty acids have an effect on gene expression and the liver. They are not only used as an energy source and as components of membrane phospholipids, but also as important mediators of gene regulation [53].

Analysis of total ω-3 fatty acids (Table III), revealed that Catfish and Disc have higher values than others species by however and Disc presented the highest value of ω-6 fatty acids.

Piggot and Tucker [35] suggested that the ω-3:ω-6 ratio is a better index in comparing relative nutritional value of fish oils of different species. Table III shows that ratios of ω-3: ω-6 oils extracted from the fish species studied. However, there is not a recommended intake in terms of ω-3:ω-6 ratios but evidence in wild animals and estimated nutrient intake during human evolution suggest a diet ratio of 1:1-1:5 [45; 54].

When oil is rich in ω-3 polyunsaturated fatty acids, ω-3:ω-6 ratio is greater. Belt (*Trichius Lepterus*) and Disc have a higher ω-3:ω-6 ratio (2.90) while Red carp contained the lower ω-3:ω-6 ratio (1.40). All these six fish species had ω-3/ω-6 ratio within the recommended ratio. The fish identified in this study were found to be good sources of marine PUFA. Studies in Japan showed that people who eat fish about twice a week (240 g total weekly intake) have lower risks of heart attacks than people who rarely eat fish [55].

3.3 AMINO ACID COMPOSITION

The amino acid composition (mg/g of total protein) is illustrated in Table IV. From this table it appears that these fish species are composed of 16 amino acids in varying amounts.

From this Table it is clear that glutamic acid is the major amino acid in all species of fish. Its content ranges from 161.51 to 190.30 mg/g of protein. Disc (*Discus Symphysadon*) has the highest glutamic acid content (190.30 mg/g of protein) while Catfish (*Arius Maculatus*) has the lowest of glutamic acid content (161.51 mg/g of protein). Aspartic acid is another predominant amino acid present in all these species (ranging from 108.62 to 148.16 mg/g of total protein). Disc has the highest aspartic acid content (148.16 mg/g of total protein).

Both fatty and amino acids are the important components for healing processes. Any deficiency in these essential components will hinder the recovery process. In addition to glycine, which is one of the major components of human skin collagen, together with other essential amino acids such as alanine, proline, arginine, serine, isoleucine and phenylalanine form a polypeptide that will promote regrowth and tissue healing [56].

The amino acid composition of Herring (*Clupea harengus*) in this study is different from that found by Subramaniam *et al*. [37]. The values of essential amino acids of Herring analyzed by Subramaniam *et al*. [37] are higher than those of the Wouri river coast (serine: 41.5 mg/g of protein, arginine: 82.7 mg/g of protein, alanine: 81.9 mg/100 g protein, proline: 50.8 mg/g of protein). Certain amino acids like hydroxyproline and methionine found by Subramanian *et al*. [37] in Herring fish are absent in Herring commercialized on the Wouri river coast. The variation in the amino acid composition of Herring may be due to the genetic make up of these species.

Among the essential amino acids, isoleucine, leucine, arginine are the most represented in all species of fish. Disc, Mullet and Catfish having the highest content of arginine (58 mg/g of protein), and the lowest content is obtained for the Belt species (42.47 mg/g of protein). Herring and belt having the highest content of leucine. The lowest leucine content is obtained from Disc (83.39 mg/g of protein) and the lowest phenylalanine is obtained from the Catfish (31.70 mg/g of protein).

Table IV - Amino acid composition (mg/g) of six fish species of Wouri river coast in Douala, Cameroon

AA	Catfish	Herring	Red Carp	Disc	Mullet	Belt
ASP	108.62±4.75	122.43±4.99	128.70±2.56	148.16±1.31	139.09±1.24	129.84±0.98
GLU	161.51±7.06	171.02±6.98	172.82±3.43	190.30±1.69	173.95±1.55	176.39±1.33
SER	33.13±1.44	37.42±1.5 3	25.61±0.51	51.40±0.46	30.24±0.27	22.76±0.17
GLY	70.80±3.09	60.80±2.48	64.93±1.29	53.44±0.47	64.44±0.57	52.65±0.40
HIS	48.11±2.10	35.03±1.43	27.70±0.55	64.35±0.57	37.78±0.30	45.93±0.35
ARG	57.64±2.51	51.54±2.10	55.82±1.11	57.08±0.51	57.43±0.51	42.47±0.32
THR	35.41±1.55	31.60±1.29	31.50±0.62	32.02±0.28	33.27±0.29	26.33±0.20
ALA	55.31±2.42	48.61±1.98	58.65±1.16	37.62±0.33	52.68±0.47	54.60±0.41
PRO	72.30±3.15	59.40±2.43	81.86±1.63	57.67±0.51	76.27±0.68	68.31±0.52
TYR	22.52±0.98	20.82±0.85	20.20±0.40	18.32±0.16	20.08±0.18	21.16±0.16
VAL	25.53±1.10	26.31±1.07	25.01±0.50	21.22±0.19	24.32±0.22	25.08±0.19
MET	28.31±1.24	29.14±1.19	27.71±0.55	22.06±0.19	24.51±0.22	27.11±0.20
CYS	nq	nq	nq	nq	nq	nq
ILE	93.02±4.06	76.30±3.11	59.50±1.18	70.24±0.62	72.53±0.64	91.49±0.69
LEU	86.74±3.79	101.12±4.13	98.44±1.92	83.39±0.74	93.27±0.83	102.06±0.77
PHE	31.70±1.38	57.13±2.33	54.47±1.08	32.18±0.28	35.37±0.31	39.07±0.30
LYS	69.41±3.04	71.63±2.92	69.03±1.37	60.50±0.54	68.69±0.61	74.68±0.57

Values are mean ± SD of two separate determinations. nq: no quantifiable.

In all species of fish, glycine and arachidonic acid were found. These two fatty and amino acids in the form of lipoamine play a key role in the edema treatment and pain [57].

3.4 MINERAL CONTENTS

Table V shows the composition of minerals of six fish species commercialised in the Wouri river coast in Douala, Cameroon.

Calcium (Ca) content of raw fish species was found to be 4080 to 18600 mg/kg. Herring (*Clupea harengus*) is very rich in calcium (18600 mg/kg) while the Disc (*Discus Symphysadon*) has the lowest calcium content (4080 mg/kg). However, the value of Ca obtained in this study is higher than that reported by Subramanian *et al.* [38] for the same species.

Magnesium (Mg) content was found to be 1021 to 9307 mg/kg. The highest magnesium content (9307 mg/kg) is obtained from Herring (*Clupea harengus*) fish. Disc has the lowest value of the magnesium content (1021 mg/kg). These values of Mg from these studies are higher than those reported by Wheaton and Lawson [58] (170 mg/kg) and Lall [59] (250 mg/kg).

Potassium (K) content in the different fish species ranged from 6389 mg/kg to 10063 mg/kg. This content remains high in Herring (*Clupea harengus*) (10063 mg/kg) and low in the Belt (*Trichius Lepterus*) (6389 mg/kg). These values are higher than K contents obtained from trout described by Wheaton and Lawson [58] (2800-3500 mg/kg), but remain lower than those found by Subramanian *et al*. [37] (36790 mg/kg).

The sodium (Na) content in raw fish ranged from 517 mg/kg to 1156 mg/kg. This content remains high in Herring *(Clupea harengus*) (1156 mg/kg). The lowest sodium level is obtained from Belt (517mg/kg). These values are low compared to those found by Subraminiam Sathivel *et al*. [38]; and Akinneye [60].

Zinc (Zn) is poorly represented in these fish of the Wouri river coast compared to other minerals. Zinc content ranged from 13.75 mg/kg to 187.49 mg/kg. Mullet (*Semotilus atromaculatus*) has the highest content of zinc (187.49 mg/kg) while Belt (*Trichius Lepterus*) maintained the lowest value of zinc (13.75 mg/kg). Subramanian *et al*. [38] showed that the zinc content in the Herring ranges from 9.20 mg/kg to 39.50 mg/kg.

Phosphorus (P) content of these fish species was found to range from 61.70 to 136.70 mg/kg. Red Carp (*Cyprinus carpio*) obtained the highest value of phosphorus (136.70 mg/kg) while Belt (*Trichius lepterus*) has the lowest phosphorus content (61.7 mg/kg). These phosphorus values are lower than those reported by Nalan *et al*. [61]; Wheaton and Lawson [58] (170 mg/kg).

Of these fat fish, Herring is the species which is rich in Ca, Mg, K and Na. The content of Zn and P in all species are lower compared to other minerals. The variation of mineral content from one species to another may be due to the chemical form of these minerals, or their concentrations in their natural environment [62; 63].

4. CONCLUSION

In conclusion, based on our findings, Catfish, Red carp, Belt, Herring and Disc fish species collected on the Wouri river coast are the fat fish. Mullet is a medium fat fish. All these species are good sources of fatty acids and protein, amino acids and essential minerals. The essential fatty acid such as DHA and EPA present in these fish species play an important role in maintaining good health. These fish may provide an alternative source of protein and fat for the populations of developing countries. Unsaturated fatty acids naturally present in the oil of these fish are precious and fragile molecules. Their sensitivity to oxidation and peroxidation are facts well known leading to fat rancidity. Therefore, care for their conservation and changes must be taken into account to avoid the deterioration of unsaturated fatty acids which have a nutritional and pharmacological importance.

REFERENCES

[1] H.V. Thurman, H.H. Webber, Marine Biology. Charles E. Merrill publishing C.A. bell and howell co. Columbus, Ohio (1984).

[2] R.M. Love, The chemical biology of fishes, Vol. *2*, Advances 1968-1977 with a supplementary key to the chemical literature. Academic press, London, P943 (1980).

[3] M. Benion, Introductory foods (7 Eds.). MacMollan: New York, USA. (1997).

[4] Jacquot, Organic constituents of fish and oth-

Table V - Mineral composition of six raw fish species commercialised in the Wouri river coast in Cameroon

	Ca (mg/kg)	Mg (mg/kg)	K (mg/kg)	Na (mg/kg)	Zn (mg/kg)	P (mg/kg)
Belt	5280	1851	6389	517	13.75	61.70
Herring	18600	9307	10063	1156	23.33	115.0
Catfish	6240	3353	6833	844	103.75	86.20
Disc	4080	1021	7408	1073	42.91	121.70
Red Carp	14480	4666	7526	917	40.00	136.70
Mullet	5280	1628	7644	917	187.49	74.20

ers aquatic animal foods. Ing. Borgstron, fish as food Vol. *1*, 146-209. New York: academic press, USA (1961).
[5] A. Samba, Collecte et traitement des statistiques de pèche artisanale au Gabon, au Cameroun et au Togo, COPA CE/Tech., 86-87, (1986).
[6] P.W. Baker, G.F. Gibbong, Effect of dietary fish oil on the sensitivity of hepatic lipid metabolism to regulation by insulin. Journal of lipid Reseach *41*, 716-727, (2000).
[7] E. Noctron, R. Macfarlene, Lipid class composition of the viviparous yellowtail rock fish biology *957(54)*, 1287-1299, (1999).
[8] W.C. Bowman, M.J. Rand, Textbook of pharmacology (2nd ed.). Oxford: Blackwell, (1980).
[9] R.A. Gibson, Australian fish- An excellent source of both arachidonic acid andpolyunsaturated fatty acids, Lipids *18*, 743-752, (1983).
[10] B. Amiramrazer, N. Kmin, P. Fiorenza, O. Mark, Dietary fish oil inhibits Δ6-desaturase Activity in vivo. Journal of American Oil Chemistry Society 2*(75),* 241-245, (1998).
[11] C. Alasalvar, K.D.A. Tylor, E. Zubcov, F. Shahidi & M. Alexis, Differentiation of cultured and wild sea bass (*Dicentrachus labrax*): Total lipid content, fatty acids and trace mineral composition. Food Chemistry *9(2),* 154-150, (2002).
[12] D.J. Holub, B.J. Holub, Oméga-3 fatty acids from fish oils and cardiovascular disease. Molecular Cell Biochemistry *263*, 217-225, (2004).
[13] P.C. Calder, Long-chain n-3 fatty acids ans cardiovascular disease: futher evidence and insights. Nutrition Research *24*, 761-772, (2004).
[14] T.A. Mori, L.J. Berlin, Omega fatty acids and inflammation. Curr. Atheroscler. Rep. *(6)*, 461-467, (2004).
[15] J.A. Glonset, Fish fatty acids and human health. New England journal of Medecine, Waltam, Vol. *312* n°19, 1253-1254, (1985).
[16] W.E. Conner, The beneficial effects of omega-3 fatty acid: cardio vascular disease and neurodevelopment. Current opinion in Lipodology *8*, 1-3, (1997).
[17] W.E. Connor, The importance of n-3 fatty acids in health and desease. Am j. clin. Nutria. *71*, (1 suppl):171s5s, (2000).
[18] P. Angerer, C. Von Schucky, n-3 fatty polyunsaturated fatty acids and the cardiovascular system. Curr Opin Lipidol *11*(1), 57-63, (2000).
[19] FAO, United Nations Food & Agriculture Organization, Nutritional elements of fish, FAO Rome, (2005).
[20] J.H. Chyun, P. Griminger, Improvement of nitrogen retention by arginine and glycine supplementation and its relation to collagen synthesis in traumatized mature and ageing rats. Journal of Nutrition *114*, 1705-1715, (1984).
[21] Hallberyl, ASPN. Iron nutrition in heath and desease. John libbey ed., London, P964, (1996).
[22] A.S. Rahman; S.H. The; H. Osman, N.M. Daud, Fatty acid composition of some Malaysian freshwater fish. Food Chemistry *54*, 45-59, (1995).
[23] T.L. Hearn, S.A. Sgoutas, J.A. Hearn, D.S. Sgoutas, Polyunsaturated fatty acids and fat in fish flesh for selecting species for health benefits. Journal of food science 52(5)*,* 1209-1215, (1987).
[24] N. Colince, Le Cameroun partie à la convention Ramsar, enjeux et défis. The Cameroon Westland Forum, Vol. *1*, Issue 1, 3, (2004).
[25] L.F. Nseumi, Alerte ! Le Wouri, un égout à risque maximum. Le quotidien Cameroun Link, (2004).
[26] M. Viallet, Publication de doual'art, dans le cadre des liquid projets du sud 2010. liquid n°1 Janvier, Fevrir, Marc, 5, (2009).
[27] AOAC, Official methods of analysis of the association of official analysis chemists (14ed.). Washington (DC): Association of Official Analytical Chemists, (1984).
[28] A.C. Bligh, W.J. Dyer, A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology *37*, 911-917, (1959).
[29] L.D. Metcalfe, A.A. Schmitz, J.R. Pelka, BF3-methanolprocedure for rapid quantitative preparation of methyl esters from lipids. Analytical Chemistry *38*, 514, (1966).
[30] B.A. Bidlingmeyer, S.A. Cohen, T.L. Tarvin, B. Frost, A new, rapid, high sensitivity analysis of amino acid in food type samples. Journal of Association Official Analytical Chemistry *70*, 241-247, (1987).
[31] P. Wolley, S. Petersen, Lipase: Their structure, biochemistry and application. Cambridge University press. Cambridge, (1996).
[32] A. Suriah Rahman, T.S. Huah, O. Hassan, N.M. Daud, Fatty acid composition of some Malaysian freshwater fish. Journal of Food Chemistry *54*, 45-49, (1995).
[33] Huss, Quality and changes in fresh fisheries, Technical paper *348*, 195, (1995).
[34] M.I. Gurr, Role of fats in food and nutrition (2nd ed.), London, UK: Elsevier APPLIED. Science (1992).
[35] G.M. Piggot, B.W. Tucker, Effects of technology of nutrition. New York, USA: Marcel Dekker, (1990).
[36] Huss, Fresh fish quality and quality changes, Rome, Italy: F.A.O. (1998).
[37] S. Sathivel, P.J. Bechtel, J. Babbitt, W. Prinyawiwatkul, L. Loan, K.D. Reppond, Properties of protein powder from Arrowtooth *Flounder (Atheresthes stomias)* and Herring (Clupea harengus) Byproducts*.* J. Agric. Food Chem. *52*, 5040-5046, *(*2004).
[38] FAO, FAO Fisheries and Aquaculture-Chemical elements of fish. Hyyp://www.fao.org/fishery/topics/14820/en, (2008).

[39] E.N. Onyieke, E.O. Ayoologu, C.O. Ibegbulam, Evaluation of the nutritioanal value of dome crude oil in polluted freshwater fishes. Global Journal of Pure and Applied Sciences *6*, 227-233, (2000).

[40] FAO/WHO/UNU, Energy and protein requirements (WHO Tech. Report Series No. 724). WHO, Geneva, Switzerland, (1985).

[41] A.M. Liceaga-Gesualdo, Li-Chan ECY, Functional properties of hydrolysates from Herring (Clupea harrengus). Journal of Food Sciences *64*, 1000-1004, (1999).

[42] K. Azam, M.Y. Ali, Biochemical Assessment of selected fresh fish. Journal of Biological Sciences *4*, 9-10, (2004).

[43] L.E. Gutierrez, R.C.M. du Silva, Fatty acid composition of commercially important fish from Brasil. Sci. Agric. Pivacicaba 50(3), 478-483, out./dex, (1993).

[44] K. Gopa kumar, M.R. Nair., Fatty acid composition of eight species of Indian marine fish. Journal of the sciences of food and agriculture, Essex *Vol. 23*, 493-496, (1972).

[45] H. Osman, A.R. Suriah, E.C. Law, Fatty acids composition and cholesterol content of selected marine fish in Malaysian waters. Food Chemistry *73*, 55-60, (2001).

[46] F.D. Gunstone, In: An introduction to the chemistry and biochemistry of fatty acids and their glycerides chapman and hall Lid., UK, (1996).

[47] W. Steffens, Effects of variation in essential fatty acids in fish feeds on nutritive value of fresh water fish for humans. Aquacult. *151*, 97-119, (1997).

[48] A. Kolakowska, M. Szczygielski, G. Bienkiewicz, L. Zienkowicz, Some of fish species as source of n-3 polyunsaturated fatty acids. Acta Ichthyologica Et Piscatoria *30*, 59-70, (2002).

[49] A. Leaf, P.C. Webber, Cardiovascular effects of n-3 fatty acids. New England Journal of Medicine *318*, 549-555, (1988).

[50] URL, http:/www.oil of pisces.com/fish neub. Html Fish oil and Angina/hearth attack, hearth benefits of fish oils, (2002).

[51] C. Pompeia, J.S. Freitas, J.S. Kim, S.B. Zyngier, R. Curi, Arachidonic acid cytotoxicity in leukocytes: implication of oxidative stress and eicosanoid synthesis. Biology of the cell 94(4-5), 251-265, (2002).

[52] J.M. Bourre, Les bonnes graisses. Ed. Odile Jacob, (1991).

[53] T. Raclot, Acides gras alimentaires et obésité, aspects qualitatifs et quantitatifs. Oléagineux Corps Gras Lipides *7* (1), 77-85, (2000).

[54] A.P. Simopoulos , Summary of NATO advanced reseach work shop on dietary ω-3 and ω-6 fatty acids: biological effect and nutritional essentially. Journal of Nutrition *199*, 512-528, (1989).

[55] G.M. Wardlaw, P.M. Insel, M.F. Seigler, Contemporary nutrition. Issues and insight. St. Louis. USA: Mosby, (1992).

[56] M.B. Witte, F.J. Thornton, U. Tantry, A. Barbul, L-arginine supplementrationenhances diabetic wound healing: involvement of nitric oxide synthase and arginase pathways. Metabolism *51* (10), 1269-1273, (2002).

[57] S.M. Huang, T. Bosogno, T.J. Petros, Identification of a new class of molecules, the arachidonyl amino acids, and characterization of one member that inhibits pain. Journal Biological Chemistry *276*, 42639-42644, (2001).

[58] F.W. Wheaton, T.B. Lawson, Processing aquatic food products. USA: John Wiley & Sons, (1985).

[59] S.P. Lall, Vitamins in fish and shelfish. Fish and fishery products. Composition, nutritive, properties and stability. A. Ruiter Biddles Ltd. UK., 157-213, (1995).

[60] J.O. Akinneye, I.A. Amoo, S.T. Arannilewa, Effect of Drying Methods on the Nutritional Composition of Three Species of Fish (Bonga sp. Sardinella sp. and Heterotis niloticus). Journal of Fisheries International *2*, 99-103, (2007).

[61] N. Gokoglu, P. Yerlikaya, E. Cengiz, Effects of cooking methods on the proximate composition and mineral contents of rainbow trout. Food Chemistry *84*, 19-22, (2004).

[62] H. Windon, D. Stein, R. Sheldon, R.J. Smith, Comparison of trace metal concentrations in muscle of benthopelagic fish (*Coryphae noides armatus*) from the Atlantic and Pacific Oceans. Deep Sea Res. *34*, 213-220, (1987).

[63] A.H. Khan, M. Ali, S.K. Biaswas, D.A. Hadi, Trace element in marine fish from the Bay of Bengal. The Sciences of the Total Environment *16*, 12-130, (1987).

Received September 6, 2012
Accepted March 6, 2013