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Research Paper

Effects of culinary treatments on the in vitro nutritional quality and the functional properties of freshwater fishes of Cameroon: *Clarias gariepinus*, *Heterotis niloticus*, *Cyprinus carpio* and *Oreochromis niloticus*

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Abstract. Four freshwater fishes collected in Cameroon were used to determine the effect of culinary processes on their nutritional quality. They were cooked according to culinary processes common in Cameroonian households (frying, frying+boiling, boiling, roasting without seasoning and roasting with seasoning). The results showed significant decrease in protein content when the culinary treatments were compared to the control (raw fish). Indeed, a decrease in protein content (using dry matter) of about 39.03% after frying was observed whereas boiling limited the losses with a decrease of about 19.65% recorded. The lipid content of the fishes ranged from 4.57 to 8.02%, increased significantly ($P < 0.05$) after culinary treatments except in boiling. Samples had considerable minerals content for which calcium and phosphorus were the most abundant. A significant increase ($P < 0.05$) in the water absorption capacity was observed after roasting of *Clarias gariepinus, Heterotis niloticus* and *Oreochromis niloticus* (4.7 ± 0.21 ml/g). The oil absorption capacity of *O. niloticus* flours decreased significantly though it, was still higher than the threshold (0.7 and 0.9 ml/g) needed in food formulation. In general, these results suggests that frying reduced protein but increase lipid content, boiling was the best cooking treatment since little or no losses were observed in both macro and micro nutrients contents.

Keywords: Freshwater fish, culinary treatments, proximate chemical composition, mineral composition, nutritional value, functional properties.

INTRODUCTION

Fish is a foodstuff of high nutritive value and a source of the long chain polyunsaturated fatty acid content (PUFA) which plays a significant role in the nutrition of the population (FAO, 2006). It is known to be a source of protein, rich in some essential amino acids such as lysine, methionine, cysteine, threonine, and tryptophan. Fish muscle also contains micro and macro elements and fat-soluble vitamins (Larsen et al., 2007). Fish covers animal protein requirements in the majority of sub-Saharan Africa countries (FAO, 2006). Indeed, 50% of fishery products are transformed into fish meal for animal feeds (Morin, 2006).

The quality of fish protein is affected during processing as a result of the application of heat. The extent of protein denaturation depends on the cooking duration and temperature, as well as the processing facility (Sikorski, 2001). Although fish is highly consumed during meals, majority of the consumers for the majority unconsciously, focus the culinary treatment on the organoleptic characteristics. Culinary treatments generally applied in our households depend particularly on eating habits, traditions and ethnic origin. However, the result is the same: they are intended to be eaten. Early developments in the field of nutrition posited that certain substances, important for the proper functioning of the human body, are lost during cooking. Indeed, all the treatments lead to lower moisture content (Costa et al., 2013). Therefore, it is important to determine the effect of culinary treatment of fish on his nutritional quality. To date, little is known on the nutritive values of raw and cooked freshwater fish.

What would be the effect of culinary treatments on the proximate chemical and mineral composition of freshwater fish? In order to conclude whether fresh water fish produced in Cameroon can be used as an intermediate flour with good functional characteristics for food product development, it was necessary to evaluate some nutritional properties of some fishes for their transformation into flour that can be used in food formulations, so as to promote their use and therefore contribute to food security.

MATERIAL AND METHODS

Sample preparation

Fishes of weights varying from 350 to 420g were collected in the locality of Batie (Division of the Western region of Cameroon). Four species of freshwater fish are mainly cultured in the area (by farmer): *Clarias gariepinus* commonly called "bapche" by farmers, *Cyprinus carpio*, *Oreochromis niloticus* and *Heterotis niloticus* commonly called "kanga". Theses fishes were transferred alive to the laboratory. The species were specifically identified at the Biology Department of the University of Dschang (Western region of Cameroon). Upon arrival at the laboratory, they were slaughtered by removing oxygenised water and allowed to go into rigor. They were then washed with tap water for removal of the adhering blood and mucus, and placed in ice-cold water (hypothermia) for five minutes prior to eviscerating and beheading. After cleaning, they were cooked using the various culinary processes commonly used in our homes (kitchen).

Culinary treatments of the fish samples

Cooking by frying

Five pieces of 400 g each per fish species were cleaned using a kitchen knife, and placed in two litres of refined palm oil (Mayor) heated for 5 min in a deep fryer brand HQ (initial temperature of the frying oil was 180°C). Frying was performed for 10 min. The Mayor oil was used for its high saturated fatty acids content, thereby limiting oxidation reactions during the treatment. In addition, the oil was changed after each frying.

Cooking by frying followed by boiling (fry + boil)

The fishes obtained after frying under the same conditions as stated above, were introduced into 1400 ml of boiling water (initial Boiling point 95.6°C). Cooking was carried out for 5 min on a hotplate.

Cooking by boiling

Boiling was performed at approximately 100°C (with a 400 g sample in 1400 ml water) for 20 min with the use of an adjustable thermostat diver.

Cooking by roasting (roasting without seasoning and roasting with seasoning)

Selected pieces of fish of about 350 to 420 g of weight in each group were seasoned with spices (roasting with seasoning). The same operation was carried out without spices (Roasting without seasoning). Roasting was carried out for 15 min on hot coals. The roasting temperature was around 95°C measured using an electronic thermometer, model PT100.

Composition of spices used during roasting with seasoning

The composition of spices used was based on a survey carried out through consulting housewives of different areas in different towns in Cameroon. The spices used were a fried mixture (in 50 ml of the refined palm oil) of 0.5g of *Piper nigrum* (pepper), 2.9 g of *Ricinodendron heudelotii* (*Djansan*), 0.85 g of *Tetrapleura tetraptera*, 0.5 g of *Monodora myristica* (*nkui* groundnut) commonly called *pepe*, 4 g of garlic and 0.9 g of *Olax subscorpoïdera*.

Proximate composition of fish

The proximate composition analyses of homogenized samples of cooked and raw fish fillets were done in triplicate. The dried samples were reduced to powder using a kitchen blender and stored in a dessicator for subsequent analysis. Moisture content, ash content, protein and lipid contents were determined in each fish species according to the methods described by the Association of Official Analytical Chemists procedures (AOAC, 2000). Carbohydrates content was determined by difference.

Lipid extraction or defatted method

After the different culinary treatments have been applied on the fish samples, they were defatted according to the method described by Bligh and Dyer (1959) using a combination of chloroform and methanol (2:1).

Preparation of fish flours

After culinary treatments, defatted flesh was dried in the oven, *venticell 55,* at the temperature of 45°C during 24 h. After being completely dried, flesh was grinded using a blender, model *QG* and the powder obtained was sift using a granulometric sieving *tamis inox ISO 3310-1*.

Functional properties

The functional properties of each defatted fish flours were determined:

Oil Absorption Capacity (OAC) and Water Absorption Capacity (WAC)

They were determined using the method described by Lin et al. (1974). One gram of fish flour was vortex-mixed with 10 ml of sunflower oil or distilled water for 30 s. The emulsion was incubated at room temperature (about 20°C) for 30 min and then centrifuged at 13,600g for 10 min at 25°C. The supernatant was decanted and drained at 45°C for 20 min. Calculation were done using the following formulae:

$$\text{Oil Absorption Capacity (OAC)} = \frac{\text{Volume of oil absorbed}}{\text{Weight of the protein sample}}$$

$$\text{Water Absorption Capacity (WAC)} = \frac{\text{Volume of water absorbed}}{\text{Weight of the protein sample}}$$

Determination of density

50 g sample of flour was introduced into a 100 ml measuring cylinder. The sample was continually packed using a plastic measuring cylinder until of a constant volume of flour in the measuring cylinder was recorded. The density in g/cm^3 was calculated as:

$$\text{Density}(\text{g/cm}^3) = \frac{\text{Weight of flour (g)}}{\text{Volume of flour (cm}^3\text{)}}$$ (Kinsella, 1976)

Proteins solubility

The protein solubility was determined according to the method describe by Ige et al. (1984) and Oshodi and Ekperigin (1989).

Quantification of some minerals

Minerals [calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), iron (Fe) and zinc (Zn)] were quantified using complexometric EDTA and flame photometry (P and K) after mineralization according to AOAC (2000) method 995.11.

Statistical analysis

The tests were performed in triplicate and results were expressed as mean ± standard deviations. All results were subjected to the analysis of variance (ANOVA) at 0.05% probability level. The Bonferroni and Dunnet tests were used as follow-up test to ascertain the specific pairs that were significantly different using Graphpad InStat 2000 software.

RESULTS AND DISCUSSION

Proximate composition of raw fish

Moisture content

The average values of the moisture content in *Clarias gariepinus, Heterotis niloticus*, *Cyprinus carpio* and *Oreochromis niloticus* are presented in Table 1. It appears that these species are composed mostly of water like most others living things with moisture content of 80.90, 80.07, 79.95 and 79.00% respectively for *Clarias gariepinus, Heterotis niloticus, Cyprinus carpio* and the *Oreochromis niloticus*. These results are similar to those (66 to 81%) found by Stanby (1962) and Love (1970) in fish muscles. Moreover, Farhat and Abdul (2011) revealed that, the moisture content of *Cyprinus carpio* (red Carpus) was close to the value obtained during this study (78.30%).

Protein content

Protein content obtained before the culinary treatments was 84.59 ± 0.45, 87.61 ± 0.32, 84.79 ± 1.12 and 81.69 ± 0.75%, respectively for *C. gariepinus, H. niloticus, C. carpio* and *O. niloticus* (Table 1). This variation might be due to the fish feed which could have varied from one pond to another according to food available. The protein contents of *O. niloticus* are higher than those reported by Onyeike et al. (2000) of 50 to 55%.

Table 1. Proximate composition of the freshwater fish of Batie.

Components	*Clarias gariepinus*	*Heterotis niloticus*	*Cyprinus carpio*	*Oreochromis niloticus*
Moisture content (%WM)	80.90 ± 0.27	80.00 ± 0.07	79.95 ± 0.10	79.00 ± 0.57
proteins Content (%DM)	84.59 ± 0.45	87.61 ± 0.32	84.79 ± 1.12	81.69 ± 0.75
Lipids (%DM)	6.11 ± 0.12	4.20 ± 0.14	8.05 ± 0.20	4.57 ± 0.07
Ashes (%DM)	8.24 ± 0.14	7.57 ± 0.11	7.23 ± 0.22	8.02 ± 0.09
Carbohydrates (%DM)	1.06 ± 0.10	0.62 ± 0.22	0.21 ± 0.06	5.72 ± 0.22

DM: Dry matter, WM: Wet matter; n = 3.

Lipid content

The lipid content of fish samples are presented in Table 1. The results showed that these fish are sources of fat with 6.11, 4.20, 8.05 and 4.57% for *C. gariepinus*, *H. niloticus*, *C. carpio* and *O. niloticus*, respectively. Suriah et al. (1995) classified fish species according to their lipid content as: thin fish (<5%), semi-fat fish (5 to 10%) and fat fish (>10%). Based on this classification, we concluded that *C. gariepinus* and *C. carpio* are semi-fat fish whereas *O. niloticus* and *H. niloticus* are thin fish. The lipid content reported during this study was in the interval obtained by Stansby (1962) and Love (1970) on fish muscles (0.2 to 25% of lipid). The fishing tropical zone can explain the differences observed. Indeed, Shirai et al. (2002) found that lipid content of Japanese sardine (*Sardino psmelanostictus*) was high in summer and low in winter. Moreover, according to Bandarra et al. (2001), the variation of the chemical composition of fish is closely related to its food.

Ash content

Ash content of fishes varies we analysed varies from 7.57 to 8.24% (Table 1). Compared to meat products, freshwater fish are rich in minerals thereby constituting a good source. These results corroborate findings by other authors such as Farhat and Abdul (2011) who obtained an ash content ranging between 7.14 and 7.91 % for *Cyprinus carpio*. These contents are however lower than those found by Shirai et al. (2002) with values varying from 9 to 22% on fish.

Carbohydrates content

Carbohydrates content are low for *H. niloticus* and *C. carpio* (0.62 and 0.21%, respectively) as presented in Table 1. This variation could be responsible for the capacity of these fish to accumulate energy. The decrease in carbohydrates content might be due to the efforts provided during short migration. These results corroborate those obtained by Stansby (1962) and Love (1970) on fish muscles. However, carbohydrates contents of *C. gariepinus* and *O. niloticus* varied from 1.06 to 5.72%, respectively.

Mineral composition

Table 2 presents the values of some mineral elements in freshwater fish of Batié. This study revealed that *C. carpio* is the richest in calcium (4134.40 mg/kg), while *O. niloticus* has the lowest calcium content (1286.00 mg/kg). The calcium content of these freshwater fish is higher than that reported by Subramaniam et al. (2004). These values are largely higher than the daily recommended value (700 mg per day). The highest iron content is 75.84 mg/kg in *C. carpio*, while *H. niloticus* has the lowest iron content 10.78 mg/kg. Freshwater fish would be very good sources of iron. Phosphorus contents, although abundant in all species, remained higher than those reported by Nalan et al. (2004) and Wheaton and Lawson (1985) (1,700 mg/kg).

Effects of culinary treatments on the proximate chemical composition of *Clarias gariepinus, Heterotis niloticus, Cyprinus carpio* and *Oreochromis niloticus*

Effects of frying

The proximate composition obtained after frying is presented in Tables 3, 4, 5 and 6. A significant decrease ($P < 0.05$) is observed between values of the control and those obtained after culinary treatments. A decrease of about 38% in protein content for *C. gariepinus*, 50% for *H. niloticus*, 34.84% for *C. carpio*, and 33.30% for *O. niloticus* is observed after frying. This reduction is linked to the moisture content and to a significant increase ($P < 0.05$) in lipid, carbohydrates and ash content.

The reduction of protein content might be explained by the exchange that has occurred between fish and frying oil which takes place at high temperatures. In fact, during frying, lipid content increases due to the exchange which occurs during this operation. The transfer of heat in the fryer is complex (Baumann and Escher, 1995). Thermal transfer from oil to products would be effective during evaporation of water in fish during frying. Oil absorption in fish is explained by two mechanisms: a continuous absorption of oil in order to replace evaporated water in

Table 2. Proximate mineral composition of freshwater fish.

Mineral in mg/kg (DM)	K	Na	Ca	Mg	P	Fe
Oreochromis niloticus	758.70 ± 23.11	1346.00 ± 10.08	1286.00 ± 29.22	434.00 ± 0.18	3566.00 ± 12.22	55.43 ± 1.02
Clarias gariepinus	796.00 ± 12.21	1346.00 ± 0.00	2598.00 ± 65.22	924.00 ± 12.22	3025.00 ± 45.22	58.64 ± 0.11
Cyprinus carpio	659.20 ± 23.22	1346.00 ± 11.12	4134.40 ± 54.89	1498.00 ± 4.87	3479.00 ± 32.22	75.84 ± 1.09
Heterotis niloticus	733.80 ± 16.44	938.00 ± 0.00	2054.00 ± 90.51	721.00 ± 2.75	8588.00 ± 55.55	10.78 ± 0.10

Fe: Iron, Ca: Calcium, P: Phosphorus; Mg: Magnesium K: Potassium; Na: Sodium; n = 3.

Table 3. Effects of culinary treatments on the proximate composition of *Clarias gariepinus.*

Culinary treatments	W (%WM)	Protein (%DM)	Lipid (%DM)	Ash (%DM)	C (%DM)	E (Kcal) /100 g DM
Control (raw)	80.90 ± 0.27^{a}	84.59 ± 0.40^{a}	6.11 ± 0.10^{a}	8.24 ± 0.14^{a}	1.06 ± 0.10^{a}	397.59 ± 12.54^{a}
Frying	66.76 ± 3.24^{b}	52.20 ± 0.45^{b}	26.62 ± 0.32^{b}	12.11 ± 0.16^{b}	9.07 ± 0.23^{b}	484.66 ± 14.55^{b}
Fry + Boil	72.06 ± 2.45^{b}	57.61 ± 0.12^{c}	19.77 ± 0.50^{bd}	11.61 ± 0.10^{bc}	11.01 ± 0.08^{c}	452.41 ± 24.33^{b}
Boiling	77.26 ± 0.12^{a}	66.06 ± 0.45^{d}	04.73 ± 0.21^{a}	9.65 ± 0.09^{d}	19.56 ± 0.07^{d}	385.05 ± 15.22^{a}
Roasting ws	78.77 ± 0.60^{ac}	62.21 ± 0.40^{e}	13.87 ± 0.35^{b}	10.47 ± 0.11^{e}	13.45 ± 0.15^{e}	427.47 ± 14.77^{a}
Roasting WS	72.34 ± 1.42^{bc}	54.85 ± 0.41^{f}	9.38 ± 0.09^{c}	11.82 ± 0.15^{b}	23.95 ± 0.11^{f}	399.62 ± 19.21^{a}

The values carrying different letters are significantly different among raw and fish at (P<0.05).The results presented are the means of three values followed by their standard deviation. W: Moisture content, C: Carbohydrates content, E: Energy value, Kcal: kilo calorie, WM: wet Matter, DM: dry Matter, Fry+Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. The crude energy of the modes was calculated while referring to the values of combustion of different, the nutriments base from 4 kcal for 1g of protein, 4 kcal for 1 g of carbohydrate and 9 kcal for 1 g of lipid, n = 3.

fish, and by the absorption of oil that occurs mainly after frying, during cooling (Saguy, 2003). Similar results have been reported for African catfish fried in sunflower oil (Rosa et al., 2007). Indeed, Rossell (2001) showed that the quantity of oil, absorbed during frying treatment, increases according to the quantity of moisture lost because oil will partly replace the space left by evaporation of water (Bouchon, 2009).

Effects of frying followed by boiling (fry + boil)

Tables 3, 4, 5 and 6 present the values of the proximate composition obtained after Frying followed by Boiling. We can observe a significant fall (P < 0.05) in protein content after this culinary treatment. A reduction of protein content of about 31.10% in *C. gariepinus*, of 25.67% in *H. niloticus*, of 36.28% in *C. carpio*, and of 33.00 % in *O. niloticus* was recorded. Thus, the significant reduction (P < 0.05) of oil content compared to the frying, might be explained by exchange of components (that is, some are extracted from boiling medium while others are introduced). This absorption during frying would permit the release of oils. Bergquist (1977) reveals that, the heat treatment in hydrated medium, allows the dissociation of the lipid compounds.

Effects of boiling

Tables 3, 4, 5 and 6 present the values of the proximate chemical composition obtained after boiling. They reveal significant reductions (P < 0.05) in the protein content between the values of the Control and those obtained after culinary treatments. A decrease in the protein content of about 21.90% in *C. gariepinus,* of 16.99% in *H. niloticus*, of 20.66% in *C. carpio* and of 19.05% in *O. niloticus* was observed. The significant reduction (P < 0.05) of oil content could be explained by the exchange occurring during cooking. Indeed, during boiling, water permeates fish, and the compounds they contain which can be largely soluble materials (amino acids, monosaccharides) are extracted. At the boiling point (100°C), the mixture is degassed and helps in reducing lipids' oxidation and proteins' reactions, hence higher protein content compared to other culinary treatments. In addition, the hydrated environment would favour Maillard reaction and, therefore reduce the flavours. These results corroborate those obtained by Bergquist et al. (1977), where the hydrated medium led to protein loss as a result of the Maillard reaction during the heat treatment.

Effects of roasting with seasoning

The values of the proximate chemical composition obtained after roasting with seasoning are presented in Tables 3, 4, 5 and 6. They reveal significant reductions (P < 0.05) between the control values and those obtained after culinary treatments. These treatments lead to a decrease in protein content of 26.45% for *C. gariepinus*,

Table 4. Effects of culinary treatments on the proximate composition of *Heterotis niloticus.*

Culinary treatments	W (%WM)	Protein (%DM)	Lipid (%DM)	Ash (%DM)	C (%DM)	E (Kcal) /100 g DM
Control (raw)	80.00 ± 0.07[a]	87.61 ± 0.30[a]	4.20 ± 0.14[a]	7.57 ± 0.11[a]	0.62 ± 0.22[a]	390.72 ± 10.44[a]
Frying	49.03 ± 0.50[b]	42.48 ± 0.53[b]	25.82 ± 1.02[b]	10.58 ± 0.13[b]	21.12 ± 0.11[b]	486.78 ± 12.22[b]
Fry + Boil	73.40 ± 0.50[c]	65.12 ± 0.26[c]	17.39 ± 0.35[bd]	12.79 ± 0.13[c]	5.09 ± 0.13[c]	437.35 ± 24.02[c]
Boiling	76.03 ± 0.04[c]	72.72 ± 1.01[d]	1.58 ± 0.09[c]	8.99 ± 0.12[d]	17.71 ± 0.09[d]	375.14 ± 17.11[a]
Roasting ws	71.07 ± 1.59[d]	63.58 ± 0.88[e]	10.61 ± 0.10[b]	12.29 ± 0.07[e]	13.52 ± 0.21[e]	403.89 ± 16.22[a]
Roasting WS	74.38 ± 0.43[c]	55.85 ± 0.45[f]	8.67 ± 0.77[b]	11.06 ± 0.18[f]	24.42 ± 0.09[f]	399.11 ± 10.01[a]

The values carrying different letters are significantly different among raw and fish at (P < 0.05).The results presented are the means of three values followed by their standard deviation. W: Moisture content, C: Carbohydrates content, E: Energy value, Kcal: kilo calorie, WM: wet Matter, DM: dry Matter, Fry + Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. The crude energy of the modes was calculated while referring to the combustion values of the different nutrients: 4 kcal for 1 g of protein, 4 kcal for 1 g of carbohydrate and 9 kcal for 1 g of lipid, n = 3.

Table 5. Effects of culinary treatments on the proximate composition of *Cyprinus carpio.*

Culinary treatments	W (%WM)	Protein (%DM)	Lipid (%DM)	Ash (%DM)	C (%DM)	E (Kcal) /100 g DM
Control (raw)	79.95 ± 0.10[a]	84.79 ± 1.10[a]	8.05 ± 0.20[a]	7.23 ± 0.22[a]	0.21 ± 0.06[a]	412.45 ± 10.21[a]
Frying	52.95 ± 3.80[b]	55.25 ± 0.75[b]	18.71 ± 0.67[b]	7.54 ± 0.31[a]	18.5 ± 0.11[b]	463.39 ± 15.11[b]
Fry + Boil	65.17 ± 0.02[c]	54.02 ± 0.47[b]	14.70 ± 0.21[ce]	7.39 ± 0.12[a]	23.89 ± 0.17[c]	443.94 ± 19.18[a]
Boiling	77.51 ± 0.06[a]	67.27 ± 0.40[c]	6.89 ± 0.26[a]	4.19 ± 0.21[b]	21.65 ± 0.22[d]	417.69 ± 13.77[a]
Roasting ws	73.95 ± 1.21[ac]	71.26 ± 0.41[d]	12.01 ± 0.77[c]	7.25 ± 0.33[a]	9.49 ± 0.22[e]	431.09 ± 18.11[a]
Roasting WS	74.02 ± 2.27[a]	64.44 ± 0.87[e]	9.66 ± 0.22[ad]	5.18 ± 0.22[c]	20.72 ± 0.09[f]	427.58 ± 9.44[a]

The values carrying different letters are significantly different among raw and fish at (P < 0.05).The results presented are the means of three values followed by their standard deviation. W: Moisture content, C: Carbohydrates content, E: Energy value, Kcal: kilo calorie, WM: wet Matter, DM: dry Matter, Fry+Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. The crude energy of the modes was calculated while referring to the values of combustion of different, the nutriments base from 4 kcal for 1 g of protein, 4 kcal for 1 g of carbohydrate and 9 kcal for 1 g of lipid, n = 3.

27.42% for *H. niloticus*, 15.95% for *C. carpio*, and 25.11% for *O. niloticus*. The high protein content reported after roasting of seasoned fish could be due to the use of spices which in addition, present a protein content of 7.26%. During roasting, an exchange could occur between fish and spices and thus leads to the high values obtained. In fact, according to Saguy (2003) during cooking processes, exchange of lipid, protein and mineral components occur.

Effects of roasting without seasoning

Tables 3, 4, 5 and 6 present the values of the various parameters obtained after roasting without seasoning. A significant difference (P<0.05) between the control values and those obtained after this culinary treatment is observed. A decrease in protein content of about 35.15% for *C. gariepinus*, 36.25% for *H. niloticus*, 24.02% for *C. carpio* and 36.67% for *O. niloticus* is observed. This reduction is linked to the significant decrease (P < 0.05) of the moisture content and the significant increase in oil content (P < 0.05). As it can be seen, ash content obtained during this study is higher than the value obtained after roasting with seasoning. This increase could be due to the ash content of the spices used (10.33%). Roasting appears as an undeniable source of minerals but it is also a cooking process which allows the contact with benzopyrene molecules. These hydrocarbons resulting from intense heating are carcinogenic at long term depending on its accumulation in the organism.

Proteins and ash contents of the spices mixture used were 7.26% DM and 10.33% DM respectively.

Effects of culinary treatment on the mineral composition

Tables 7, 8, 9 and 10 show the mineral content of *C. carpio*, *H. niloticus, C. gariepinus* and *O. niloticus*. It appears that minerals vary significantly (P < 0.05) in some cases after cooking processes. This variation in fish tissues is similar to those obtained by Windom et al. (1987) which reported that such variation was due to the chemical forms of elements and their concentrations in the environment.

Potassium concentration decreases significantly (P <

Table 6. Effects of culinary treatments on the proximate composition of *Oreochromis niloticus.*

Culinary treatments	W (%WM)	Protein (%DM)	Lipid (%DM)	Ash (%DM)	C (%DM)	E (Kcal) /100 g DM
Control (raw)	79.00 ± 0.57[a]	81.69 ± 0.70[a]	4.57 ± 0.07[a]	8.02 ± 0.09[a]	5.72 ± 0.22[a]	390.77 ± 21.11[a]
Frying	56.91 ± 2.07[b]	54.49 ± 0.48[b]	32.10 ± 1.08[b]	7.08 ± 0.22[b]	6.33 ± 0.21[a]	532.18 ± 17.44[b]
Fry + Boil	70.34 ± 1.16[c]	54.42 ± 0.42[b]	25.43 ± 0.41[c]	7.57 ± 0.13[c]	12.58 ± 0.11[b]	496.87 ± 13.22[c]
Boiling	77.43 ± 0.75[ac]	66.12 ± 0.14[c]	3.32 ± 0.14[a]	11.13 ± 0.19[d]	19.43 ± 0.33[c]	372.08 ± 18.21[a]
Roasting ws	72.79 ± 0.93[c]	61.07 ± 0.22[d]	10.61 ± 0.03[d]	12.31 ± 0.11[e]	16.01 ± 0.45[d]	403.81 ± 19.02[a]
Roasting WS	74.28 ± 0.81[ac]	51.73 ± 0.40[e]	6.66 ± 0.32[ae]	12.89 ± 0.08[f]	28.72 ± 0.23[e]	381.74 ± 14.98[a]

The values carrying different letters are significantly different among raw and fish at (P < 0.05). The results presented are the averages of three values followed by their standard deviation. W: Moisture content, C: Carbohydrates content, E: Energy value, Kcal: kilo calorie, WM: wet Matter, DM: dry Matter, Fry + Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. The crude energy of the modes was calculated while referring to the values of combustion of different, the nutriments base from 4 kcal for 1g of protein, 4 kcal for 1 g of carbohydrate and 9 kcal for 1 g of lipid, n = 3.

Table 7. Effects of culinary treatments on the mineral content of *Cyprinus carpio.*

Minerals content (mg/1000g DM) Culinary treatments	K	Na	Ca	Mg	P	Fe
Control (raw)	659.20±23.22[a]	1346.00±11.12[a]	4134.40±54.89[a]	1498.00±4.87[a]	3479.00±32.22[a]	75.84±1.09[a]
Frying	621.90±12.14[a]	1066.00±8.33[b]	4035.00±34.38[a]	1461.00±6.75[a]	5244.00±12.44[b]	10.43±0.04[b]
Fry + Boil	385.60±15.10[b]	1066.05±12.29[b]	16268.00±87.22[b]	6034.00±3.98[b]	2274.00±10.09[c]	7.02±0.09[b]
Boiling	398.00±9.12[b]	602.09±21.32[c]	15426.00±12.32[c]	5719.00±14.22[c]	1968.00±45.12[d]	7.73±0.12[b]
Roasting ws	584.60±11.18[c]	1222.04±21.29[d]	6065.00±10.09[d]	2220.00±11.03[d]	6172.00±12.33[e]	10.71±0.17[b]
Roasting WS	584.60±11.10[c]	1346.00±13.22[a]	5768.00±13.04[e]	2109.00±9.45[e]	1853.00±19.07[d]	4.90±0.08[b]

The values carrying different letters are significantly different at P < 0.05. The results presented are the means of three values followed by their standard deviation. Fe: Iron, Ca: Calcium, P: Phosphorus; Mg: Magnesium K: Potassium Na: Sodium, Fry + Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. DM: dry Matter.

Table 8. Effects of culinary treatments on mineral content of *Heterotis niloticus.*

Minerals content (mg/1000 g DM) Culinary treatments	K	Na	Ca	Mg	P	Fe
Control (raw)	733.80±16.44[a]	938.00±0.00[a]	2054.00±90.51[a]	721.00±2.75[a]	8588.00±55.55[a]	10.78±0.10[a]
Frying	522.40±14.56[b]	938.00±11.17[a]	8591.00±89.22[b]	3164.00±3.95[b]	2045.00±45.33[b]	4.32±0.13[b]
Fry +Boil	373.10±11.23[c]	938.00±14.64[a]	7749.00±10.13[c]	2850.00±2.75[c]	2236.00±33.34[b]	5.38±0.04[c]
Boiling	509.90±7.99[b]	602.00±21.12[b]	1410.00±45.22[d]	480.00±4.23[d]	6536.00±80.33[c]	15.43±0.22[d]
Roasting ws	783.60±9.23[a]	506.00±11.21[c]	14869.00±105.23[e]	9865.00±5.45[e]	2092.00±45.22[b]	5.10±0.32[b]
Roasting WS	796.00±9.12[a]	1826.00±0.00[d]	9706.00±37.22[f]	3581.00±3.22[f]	2025.00±22.12[b]	4.45±0.14[b]

The values carrying different letters are significantly different at (P < 0.05). The results presented are the means of three values followed by their standard deviation. Fe: Iron, Ca: Calcium, P: Phosphorus; Mg: Magnesium K: Potassium Na: Sodium, Fry+Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. DM: dry Matter.

0.05) after culinary treatments. This decrease could be due to the exchange that occurs during cooking processes between the cooking environment and fish. As it can be seen, calcium, magnesium and phosphorus were the most abundant. The main changes could be due to water loss and the addition of salt during some cooking processes. Higher levels of calcium, phosphorus and magnesium in fried fish also reflect the great water loss

Table 9. Effects of culinary treatments on the mineral content *of Clarias gariepinus.*

Minerals content (mg/1000 g DM) Culinary treatments	**K**	**Na**	**Ca**	**Mg**	**P**	**Fe**
Control (raw)	796.00±12.21[a]	1346.00±0.00[a]	2598.00±65.22[a]	924.00±12.22[a]	3025.00±45.22[a]	58.64±0.11[a]
Frying	758.70±9.33[a]	1202.00±11.33[b]	15946.00±97.22[b]	5913.00±10.11[b]	2389.00±43.22[b]	5.03±0.17[b]
Fry + Boil	771.10±12.32[a]	1066.00±0.00[c]	5025.00±11.32[c]	1831.00±10.22[c]	6785.00±23.11[c]	8.21±0.11[c]
Boiling	833.30±11.22[b]	938.00±12.22[d]	11811.00±102.22[d]	4368.00±9.65[d]	3126.00±12.22[a]	5.74±0.11[d]
Roasting ws	758.70±16.22[a]	1066.00±0.00[c]	729.00±34.22[e]	226.00±0.12[e]	4972.00±39.89[d]	7.18±0.12[e]
Roasting WS	746.30±11.22[a]	1498.00±0.00[e]	1781.00±18.11[f]	619.00±2.13[f]	697.001±3.22[e]	14.60±0.00[f]

The values carrying different letters are significantly different at (P<0.05). The results presented are the means of three values followed by their standard deviation. Fe: Iron, Ca: Calcium, P: Phosphorus; Mg: Magnesium K: Potassium Na: Sodium, Fry+Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. DM: dry Matter.

Table 10. Effects of culinary treatments on the mineral content of *Oreochromis niloticus.*

Minerals content (mg/1000 g DM) Culinary treatments	**K**	**Na**	**Ca**	**Mg**	**P**	**Fe**
Control (raw)	758.70±23.11[a]	1346.00±10.08[a]	1286.00±29.22[a]	434.00±0.18[a]	3566.00±12.22[a]	55.43±1.02[a]
Frying	771.10±11.22[a]	1202.00±0.00[b]	14980.00±77.22[b]	5552.00±3.78[b]	2729.00±43.22[b]	9.37±0.23[b]
Fry + Boil	646.80±23.33[b]	1202.00±7.23[b]	4753.00±10.22[c]	1730.00±4.87[c]	3637.00±22.12[a]	7.12±0.12[c]
Boiling	746.30±10.03[a]	1202.00±9.11[b]	11464.00±19.33[d]	4238.00±21.22[d]	3082.00±9.15[c]	6.19±0.55[d]
Roasting ws	783.60±11.22[a]	1658.00±0.00[c]	7279.00±11.21[e]	2674.00±2.00[e]	7947.00±13.44[d]	10.81±0.11[b]
Roasting WS	796.00±7.22[a]	2786.00±10.12[d]	6808.00±23.22[f]	2498.00±33.21[f]	8081.00±11.98[e]	12.19±0.41[e]

The values carrying different letters are significantly different at P < 0.05. The results presented are the means of three values followed by their standard deviation. Fe: Iron, Ca: Calcium, P: Phosphorus; Mg: Magnesium K: Potassium Na: Sodium, Fry + Boil: Frying then boiling, Roasting ws: Roasting without seasoning, Roasting WS: Roasting with seasoning. DM: Dry matter.

during frying. The very high level of sodium content in roasted fish resulted from the addition of sodium chloride (table salt) to fish during its culinary preparation. Sodium concentration also shows a significant decrease ($P < 0.05$) after the cooking processes except roasting with seasoning which showed a significant increase. This significant difference could be explained as said above by its absorption by fish during roasting when spices containing salt were used. According to Epstein (1972), the predominance of sodium ion in the soil in semi-arid regions such as some African countries could also explain the higher sodium levels than those obtained in previous analyses. The mineral content of fish product is greatly diminished by cooking (Mary and Alberto, 2003).

Calcium and magnesium content increase significantly ($P < 0.05$) after culinary treatments. However, two significant decreases ($P < 0.05$) are observed, especially in the case of *C. gariepinus* after roasting. This decrease can be explained by the water loss recorded during culinary treatments. Despite the increases observed in most cases, those obtained after frying and Fry + Boil, presented a very large increase when compared to the control. Indeed, cooking of fish in a liquid medium like water leads to the modification of its structure by temperature, thus leading to a greater or lesser extent of the mineral value, by diffusion of water-soluble constituents in the cooking water, by destruction of thermolabile substances and/or oxidizable reduction. Calcium and magnesium are more soluble than others and therefore, the solubility increases their quantity. We suggest that this increase is also due to the intake of calcium by the cooking water, especially kitchen water which is classified as hard water by Lestradet and Machinot (1990).

Iron concentration decreases significantly ($P < 0.05$) after cooking processes of the different fish species used. The nature of iron could explain the decrease reported. Cooking lead to significant changes in the proportions of the four chemical forms of iron: soluble and insoluble haeme, soluble and insoluble non-haem. The results

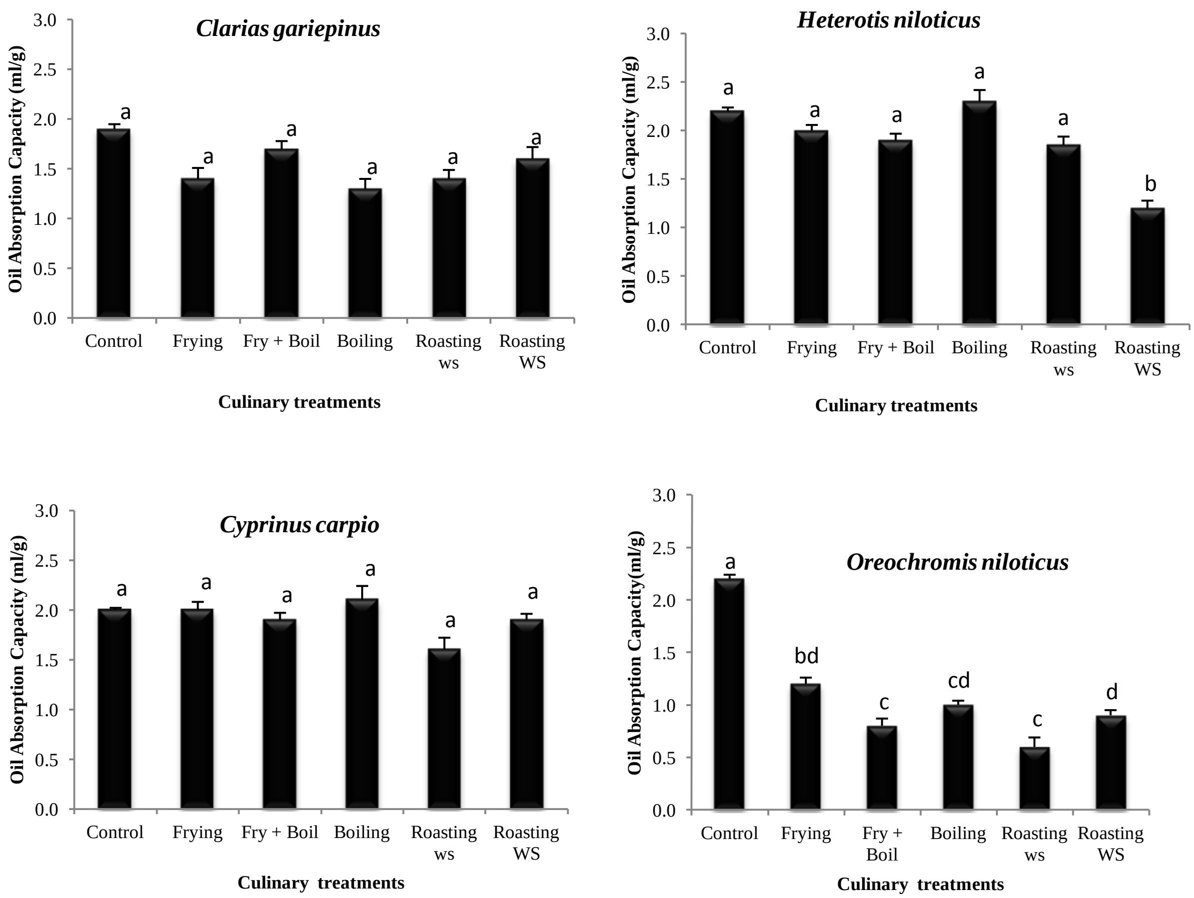

Figure 1. Effects of culinary treatments on the OAC of flour. The values carrying the different letters are significantly different with (P < 0.05). Fry+Boil = Frying followed by boiling, Roasting ws = Roasting with seasoning; Roasting WS = Roasting without seasoning n=3.

show that, most of the soluble heme iron is rapidly converted to its insoluble form during cooking and at higher temperatures; part of the haemic iron might become non-haemic iron. The amount of haemic iron found in the juice is more important than the amount contain by fish.

Effects of culinary treatments on functional properties

Effects on the Oil Absorption Capacity (OAC)

Kinsella (1976) reported that the ability of proteins to be bound to lipids is a significant phenomenon since the lipids act like flavour sensors. Figure 1 illustrates the OAC of *C. gariepinus*, *H. niloticus*, *C. carpio* and *O. niloticus* of fish flours after culinary treatments. We observed that the OAC of *C. gariepinus* and *C. carpio*, after different culinary treatments does not present a difference ($p < 0.05$), when compared to the control. Roasting with seasoning of *O. niloticus* presents a significant reduction ($p < 0.05$), compared to the control. The OAC of *H. niloticus*, also presents a significant fall ($p < 0.05$), compared to the control. Finally, all the culinary treatments applied except boiling of *C. gariepinus* and Frying followed by boiling of *C. carpio* and *H. niloticus*, increase the OAC. These reductions observed could be due to the modification of protein's conformation and thus, the denaturation of the protein's native structure, thereby leading to a more or less reticulate structure and to the formation of aggregates. These conclusions are different from those reported by Chau and Cheung (1998), who found that, high temperatures increase the hydrophobicity by exposure of hydrophobic groupings. However, the results obtained after boiling and frying followed by boiling do not affect it significantly ($p > 0.05$) in *C. carpio* and *O. niloticus* as observed by Chau and Cheung (1998).

Protein's denaturation can occur during these treatments and then, can affect their hydrophobic group. Flours deteriorated by protein's denaturation tend to form aggregates and are not well dispersed in oil leading to a reduction in the oil absorption capacity (Kinsella, 1979). These oil absorption capacities are lower than those obtained by Dangang (2009) on Atlantic salmon fish flour

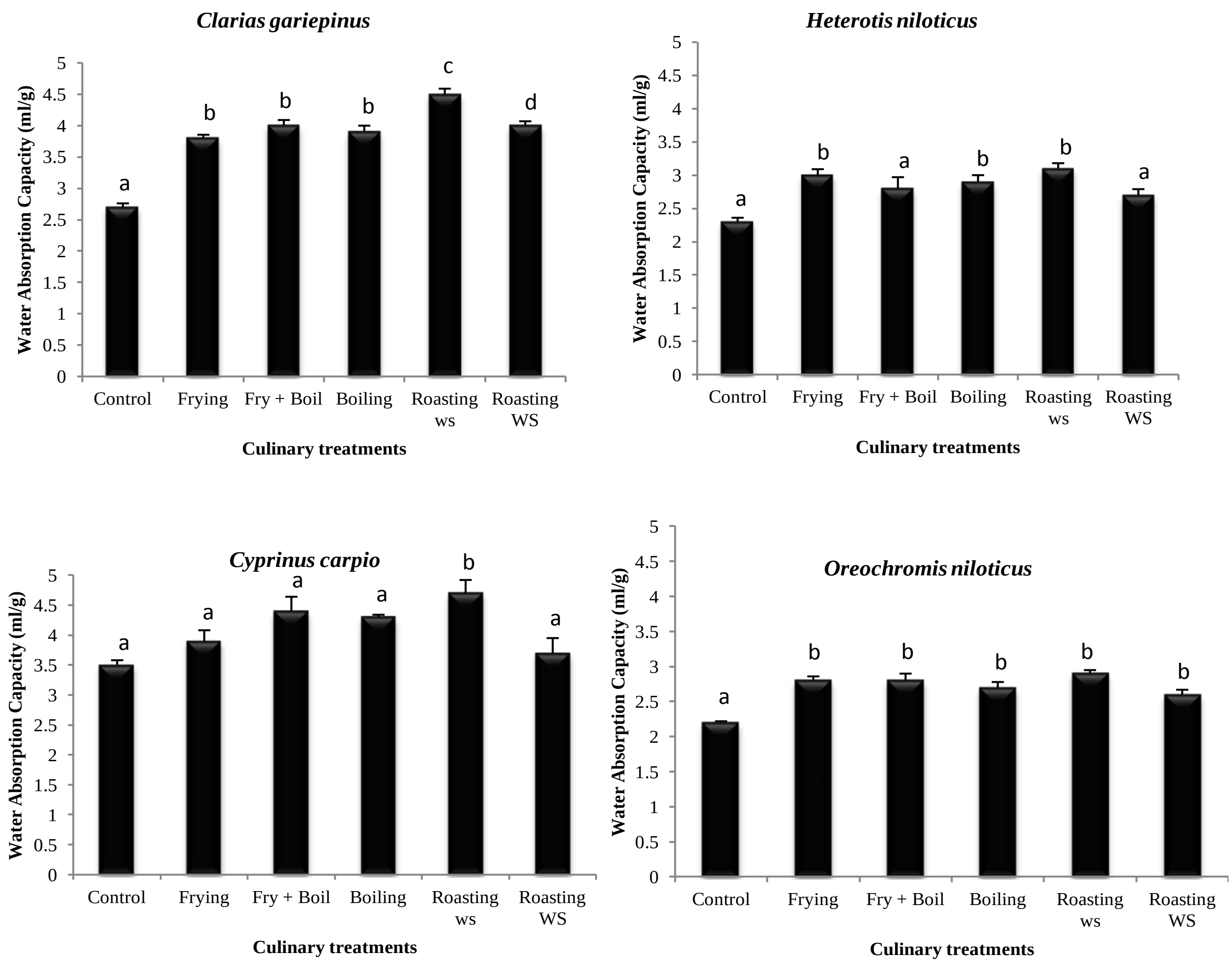

Figure 2. Water absorption capacity of flours obtained after culinary treatments. The values carrying the different letters are significantly different with (P < 0.05). Fry+Boil = Frying followed by boiling, Roasting ws = Roasting with seasoning; Roasting WS = Roasting without seasoning n=3.

(2.86 to 7.07 ml/g). This variation could be due to the cooking method, rather than temperature. The oil absorption capacities of *O. niloticus* (from 0.6 to 1.2) enabled us to say that it may be possible to use it as a weaning food.

Effects on the Water Absorption Capacity (WAC)

Water absorption capacity provides information on the hydration of proteins. This will depend on the nature of amino acids composition and protein's conformation. In this context, water absorption capacity is the ability of fish meal to retain water. Figure 2 illustrates the results of the effect of frying and frying and boiling (Fry + Boil), boiling, roasting without seasoning and roasting with seasoning on the water absorption capacity of flours. It indicates that the WAC of *C. gariepinus* and *C. carpio*, increases significantly ($p < 0.05$) compared to the control. Roasting without seasoning of *O. niloticus* showed a significant increase ($p < 0.05$). *H. niloticus* shows a significant increase ($p < 0.05$) after frying, frying followed by boiling, and roasting without seasoning when compared to control. An increase in the WAC was observed after culinary treatments. These results are similar to those found by Chau and Cheung (1998), showing that treatment preceded by boiling increased the water absorption capacity. The significant increase between roasting without seasoning and other treatments indicates that the flours obtained after treatment display greater hydrophobicity. This is due to the constant temperature during roasting. Aletor et al. (2002) considers that a product having WAC values ranging between 1.49 and 4.72 ml/g can be used in viscous foods. WAC values indicate that the flours obtained after these treatments can be used in products requiring high water retention.

Effects on the density

Figure 3 illustrates the densities of *C. gariepinus, H.*

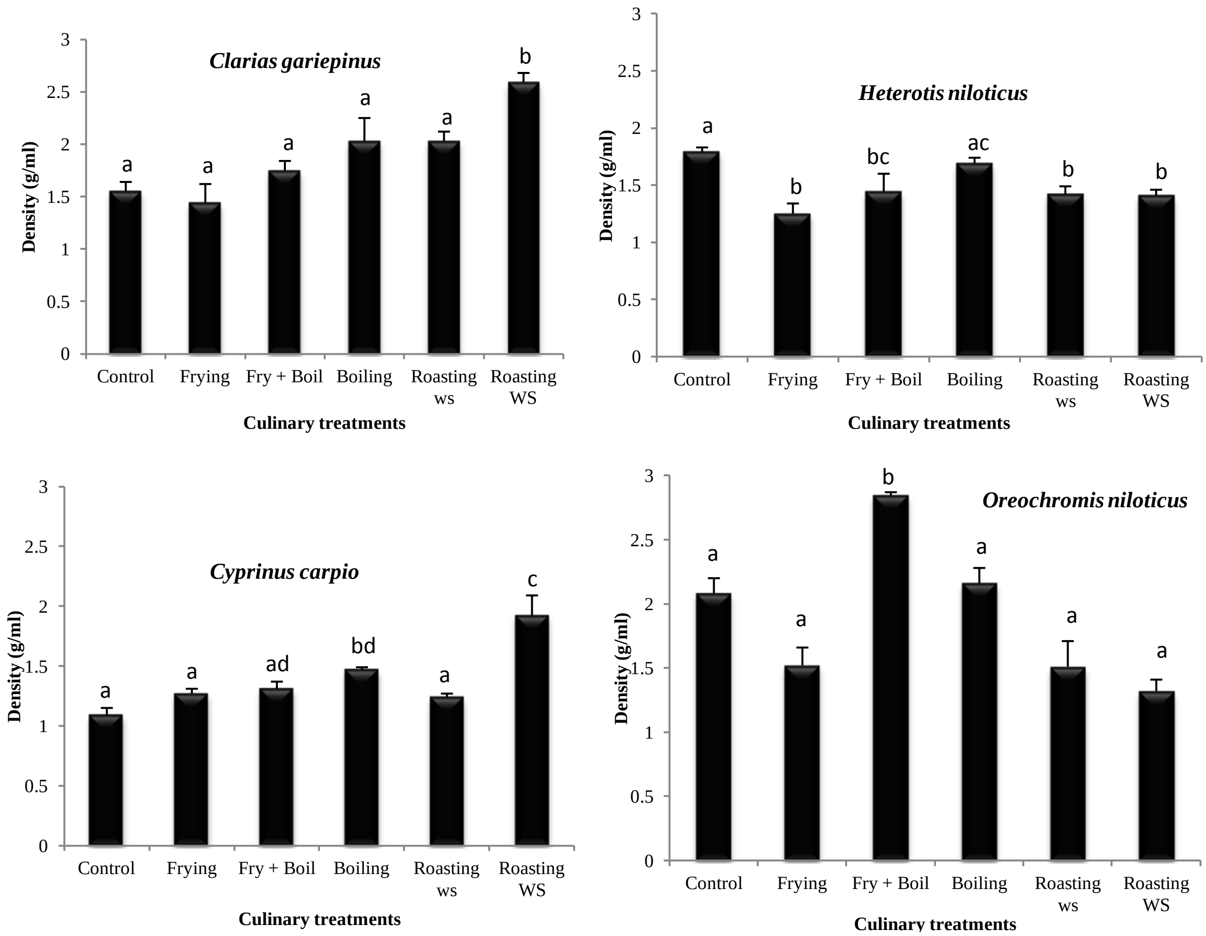

Figure 3. Effects of culinary treatments on the density flours obtained after culinary treatments. The values carrying the different letters are significantly different with P < 0.05. Fry+Boil = Frying followed by boiling, Roasting ws = Roasting with seasoning; Roasting WS = Roasting without seasoning n = 3.

niloticus, C. carpio and *O. niloticus* obtained after culinary treatments. The density of *C. gariepinus* presents a significant reduction ($p < 0.05$) after roasting without seasoning. Roasting with seasoning of *H. niloticus* also presents significant differences ($p < 0.05$). Frying followed by boiling of *O. niloticus* presents a significant difference ($p < 0.05$) compared to the control. With values ranging from 1.06 to 2.82 g/ml, the flours of *C. gariepinus*, *H. niloticus* and *O. niloticus* are denser than those of *C. carpio*. Similar conclusions were reported by Lalude and Fashakin (2006) on sorghum, soya beans and groundnuts. It is known that, density depends on the granulometry of the flours thus, increases with the smoothness of the particles. The different granulometry of fish flours caused by variations in temperature would be the cause of variable densities according to the treatment. The protein content after boiling of all fish species is highly compared to the value obtained after other culinary treatments. Fish flours of high density are needed since they help to reduce the thickness of paste, a significant factor in infantile and convalescent food. This enables us to recommend *H. niloticus* and *C. carpio*. Although some densities are reduced, all are higher than 0.4; value brought back by Lalude and Fashakin (2006) for food additives.

Effects of pH on protein solubility

The solubility of a protein is its ability to dissolve in water. This solubility depends on pH and temperature of the medium. Protein solubility of fish muscle is used as key criteria for the breakdown of proteins (Zayas, 1997).

Figure 4 shows the effect of the variation of pH on the degree of protein solubility of freshwater fishes. This solubility varies among species and may be related to changes in the surface of particles used in the building-up of each species (Cepeda et al., 1998). The solubility percentages of these fish samples vary depending on their pH, fish proteins are more soluble at pH 12. However, at pH 2 and 7 protein solubility of *C. gariepinus* is higher than others. The proteins of *O. niloticus* are less soluble at pH 2. At pH 4, the solubility percentages are the same. These species have different isoelectric points.

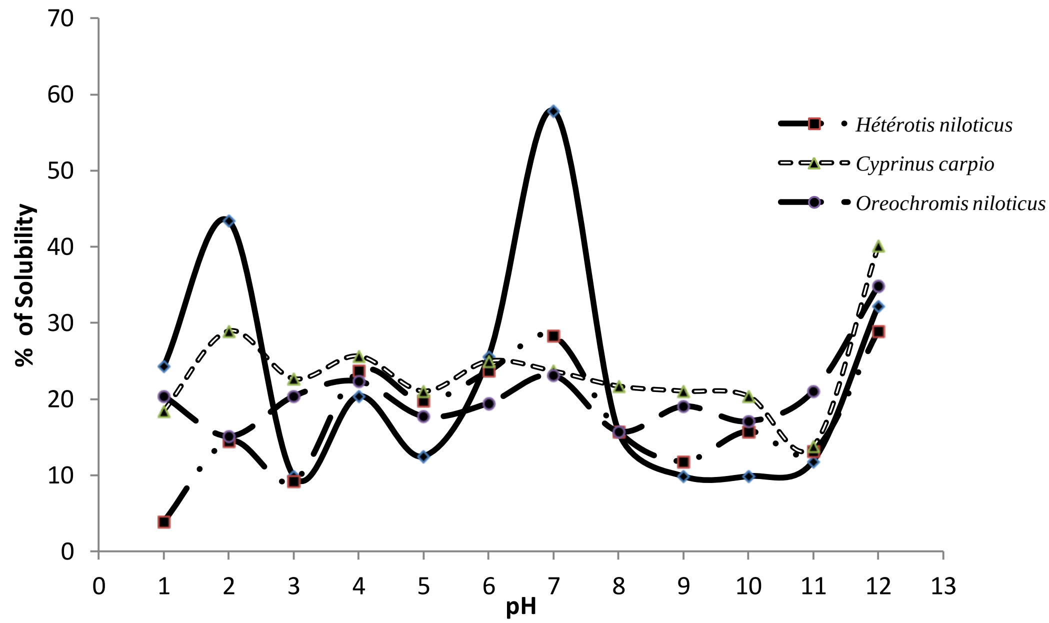

Figure 4. Solubility percentage of flours' proteins according to pH.

Protein solubility of *O. niloticus* is high at pH 3, 4, 6 and 7. These results are similar to those obtained by Kinsella (1976) on *O. niloticus* proteins that showed a high solubility (at pH 3, 5 and 6). According to Sorgentini and Wagner (2002), the appearance of a less solubility is mainly due to the peptides' net charge. The presence of an alkali would generally improve the solubility of proteins causing dissociation and disintegration of proteins. However, a high solubility with the alkali medium can also be caused by a wide proteolysis (Kinsella, 1976). In addition, Damodaran (1997) states that a lowest solubility occurs in the neighbourhoods of the isoelectric point of protein, the majority of food proteins are acid.

CONCLUSION

These studies revealed that freshwater fishes are good sources of nutrients. Indeed they can be used as food supplement especially in Africa and particularly in Cameroon to remedy nutritional deficiency (malnutrition). The proximate composition of cooked fish resulted in water loss, though the highest loss was observed in frying. The variation in oil content observed after culinary treatments depends on the treatment applied. Furthermore, the high fat content of fried fish reflects the absorption of oil. Thus, the importance of cooking for nutrients supply is essential. The decrease in protein, ash and Na content was recorded in cooked fillets. Based on caloric content, frying increased energy. Roasting certainly does not break down many proteins, but could be dangerous in future during frequent consumption. Significant increase was observed for calcium after boiling. The potassium, sodium and ion content decrease generally after culinary treatment while magnesium and phosphorus content increase and decrease after boiling according to the fish species. The effect of pH 1 to 12 on proteins has shown that most proteins are soluble in alkaline pH and that there are more than two proteins are present in fish at the isoelectric point. The high values of the water absorption capacity after the culinary treatments indicated that flours obtained can be used in food formulation, particularly in products requiring high water retention.

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