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Influence of Traditional Drying and Smoke-Drying on the Quality of Three Fish Species (*Tilapia nilotica, Silurus glanis* and *Arius parkii*) from Lagdo Lake, Cameroon

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Abstract: Traditional fishing and fish processing are a very important activities around the Lagdo lake, Cameroon. This study was carried out to investigate the influence of traditional fish processing on the nutritional and microbiological qualities. To this effect, some physico-chemical characteristics (moisture, proteins, fats, TBA index, total ash, minerals) were determined for fresh, smoked-dried and sun dried flesh of three fish species (*Tilapia nilotica*, *Silurus glanis* and *Arius parkii*) while food-spoilage and pathogenic microorganisms (*Escherichia coli*, *Staphylococcus aureus*, fecal streptococci, sulfite-reducing clostridia and moulds) were screened on the same samples. Results showed that moisture content varied between 81.49±0.35 and 84.33±1.28 g/100 g for fresh fish; between 7.58±1.13 and 8.95±1.73 g/100 g for smoked-dried fish and between 11.5±0.71 and 14.06±2.11 g/100 g for sun-dried fish. For total ash, values as high as 8.13±1.55-9.86±0.24 g/100 g were recorded in smoked-dried fish while much lower values were obtained for fresh fish. With regard to protein contents, fresh fish had lower amounts between 18.81±1.55 and 21.23±1.50g/100 g while smoked-dried had the most important protein content between 69.10±2.94 and 75.72±3.66 g/100 g. All fresh fish samples showed lower fat contents than sun-dried and smoked-dried samples. Most minerals were significantly increased by sun-drying and smoking-drying. All samples appeared to be of poor microbiological quality since *Escherichia coli*, *Staphylococcus aureus*, fecal streptococci, sulfite-reducing clostridia and moulds were detected at concentrations above recommended norms.

Key words: Fish, smoking, drying, sun drying, quality, microbiological

INTRODUCTION

In Cameroun, like in most sub-saharan Africa countries, traditional fishing is practiced in almost all rivers, lakes, ponds and represents an important part of total fish captures. It is an important sector in the national strategies of fight against poverty and food safety. One of the most important producing sites is the water reserve of the Lagdo hydroelectric dam. This lake has a surface of 700 km^2 and 11 m depth and is located in the North Cameroun region (8°53' North latitude and 13°58' East longitude). This dam was constructed between 1977 and 1982 with the double objective to produce electricity for the northern part of the country and to allow the irrigation of 15,000 ha downstream. It is estimated that the lake produces about 13,000 tons of fish per year thus, providing appreciable amount of protein to local populations. Despite the importance of traditional fishing in Lagdo, very few investments are realized in this sector in view of modernizing the activity as well as improving fresh fish preservation tool. With regard to fresh fish storage, it is estimated that 35% are lost due to the lack of cold chain.

But local population have developed traditional fish processing techniques that make use of available natural means, namely sun and wood. In this respect, they mainly sun-dry and smoke-dry more than 75% of fresh fish captured.

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Fish processing is usually carried out by women. The method includes fish scaling if necessary, evisceration, washing and draining prior to sun-drying or smoke-drying. For sun-drying, fish are exposed to sun and free air and are turned over from time to time during 48-72 h depending on the size of fish and the intensity of sun. Smoking-drying is carried out in terracotta smoking-rooms using various wood species. Fish are smoked for 2-3 h at 70-80°C, followed by mild smoking (30-35°C) for 24-48 h.

But the technology employed by local fishermen is not standardized and most parameters remain uncontrolled. Hence, such essential drying parameters as duration, air humidity and temperature are not precisely determined and mastered. In addition, hygienic conditions of fish capture, processing and storage are questionable. These might impact on nutritional value and safety of processed fish with possible food toxi-infections. The present study was therefore carried out to investigate the effect of traditional fish processing techniques (sun-drying and smoking-drying) on nutritional value and microbiological quality of three more important fish species captured in the Lagdo lake.

MATERIALS AND METHODS

Fish samples: The study focused on 3 most common and consumed fish species at the beginning of rainy season (at the end of July-at the beginning of August), namely *Tilapia nilotica*, *Silurus glanis* and *Arius parkii*. The fish were bought to the fishermen of Djogole village located on banks of Lagdo. For each species, fresh, smoke-dried and sun-dried fish were studied. Upon purchase, the fish were conditioned in sterile plastic bags under vacuum and transported in cool bags to the laboratory of the University Institute of Technology of Ngaoundere for analyses.

Determination of the nutritional value: For each species, 100 g of fresh, sun-dried and smoke-dried fish flesh were analyzed. The water contents and of total ashes were determined by normalized method. Total lipids were extracted in soxhlet using hexane and were measured according to the Russian method described by Bourely. Crude proteins were mineralized according to Kjeldhal and nitrogen obtained was measured by the method of Devani *et al*. (1989).

Crude proteins content was obtained by multiplying the nitrogen content by the conventional factor of 6.25. Minerals and heavy metals (K, Mg, Na, Zn, Ni, Cd, Pb, Cr) were determined by atomic absorption spectrometry (AAS 50B, Australia) according to the methods described, respectively by Maltida *et al*. (1991) and Atta *et al*. (1997). Sensory quality of fish, more precisely oxidative rancidity was determined by measuring Thiobarbituric Acid Reactive Substances (TBA-RS) according to the method described by Witte *et al*. (1970).

Table 1: Culture media and conditions for microbial screening

Type of microorganism	Culture media	Temperature (°C)	Incubation time
Total aerobic flora	PCA	30	24 h
Sulfite reducing anaerobes	TSN	30	24 h
Staphylococci	Chapman	37	24-48 h
Fecal coliforms	EMB	44	24 h
Fecal streptococci	Slatnez and bartley	37	24 h
Moulds	Sabouraud	25	2-5 days

Microbiological quality of fish: The microbiological quality of fish was evaluated by the method described by Mohamadou *et al*. (2009). Spoilage and pathogenic microorganisms were screened on 10 folds dilutions of fish samples. Culture media and specific conditions of culture are shown in Table1.

Statistical analyses: The values obtained for triplicate are expressed in mean±SD and compared by Analysis Of Variance (ANOVA), followed by Duncan multiple range test where significant differences are observed. Statistical analyses were carried out using Stat Graphics Plus 5.1 (Manugistic Inc., Rockville, USA).

RESULTS AND DISCUSSION

Moisture content and ashes total: Table 2 shown the average physicochemical composition of analyzed fish flesh. Moisture contents of all fresh fish were relatively high and were not significantly different ($p>0.05$). Values of 81.49±0.35-84.33±1.28% were obtained for *Tilapia nilotica* and *Silurus glanis*, respectively. These contents, close to those found by Medale is one of the factors which increase muscles spoilage speed. Preservation treatment (sun-drying, smoke-drying) reduced moisture contents to values <15%. The highest value recorded was 14.06±2.11% for dried flesh of *Tilapia nilotica*.

Whatever the species, sun-dried fish flesh contained more residual moisture than smoke-dried ones (13.92±1.24; 14.06±2.11 and 11.5±0.71%) and (7.88±1.33; 8.95±1.73 and 7.58±1.13%), respectively for the three sun-dried and smoke-dried species. This could be explained by the fact that during smoke-drying the flesh loses water in the initial phase that could be compared to cooking (the first 3 h at 80°C). In addition, a protective coating is formed due to partial carbonization of tissue and other components by wood smoke. On the contrary to sun-dried fish which tends to moisturize ambient air humidity is high, the protective coating would reduce

Table 2: Physico-chemical composition of fish flesh

		Composition				
Species	Treatments	MC (%)	TAC (%)	Proteins (g/100 g)	Fats (g/100 g)	TABRSMg of MA kg^{-1}
Arius parkii	Fresh	81.87±0.14^{a}	1.10±0.07^{a}	18.81±1.55^{a}	1.35±0.06^{a}	0.13±0.05^{a}
	Smoke-dried	7.880±1.33^{b}	8.13±1.55^{b}	71.13±3.30^{b}	2.20±0.24^{b}	0.41±0.01^{b}
	Sun-dried	13.92±1.24^{c}	4.60±0.76^{c}	51.68±2.62^{c}	3.31±0.38^{c}	0.66±0.07^{c}
Tilapia nilotica	Fresh	81.49±0.35^{a}	0.99±0.18^{a}	19.83±1.50^{a}	0.57±0.01^{a}	0.11±0.01^{a}
	Smoke-dried	8.950±1.73^{b}	9.86±0.24^{b}	69.10±2.94^{b}	0.41±0.04^{b}	0.43±0.02^{b}
	Sun-dried	14.06±2.11^{c}	4.10±0.59^{c}	52.94±2.59^{c}	0.59±0.12^{c}	0.61±0.11^{c}
Silurus glanis	Fresh	84.33±1.28^{a}	1.85±0.59^{c}	21.23±1.50^{a}	1.51±0.03^{a}	0.12±0.02^{a}
	Smoke-dried	7.580±1.13^{b}	9.75±0.43^{d}	75.72±3.66^{b}	2.97±0.62^{b}	0.96±0.26^{b}
	Sun-dried	11.50±0.71^{c}	3.52±0.34^{cd}	54.90±1.60^{c}	2.29±0.59	1.10±0.06^{c}

Means on the same column with different letters as superscript are significantly different ($p<0.05$) NB : MC = Moisture Content; TAC: Total Ash Content; TBARS = Thio-Barbituric Acid Reactive Substances; MA = Malonaldehyde

rehydration of smoke-dried. Indeed, on the contrary to cool-drying where the product does not cook, the maximum temperature being 30°C, during smoke-drying (drying in smoking-room) the product is hot-smoked, cooked and dried. This triple heat treatment may explain why smoke-dried products from Lagdo are better preserved and have lower moisture contents than those found by Maltida *et al.* (1991) for simple smoking of *Sardinella* sp. and *Tilapia nilotica* with respectively 20.70±0.3% and 42.80±0.3%. A same trend was observed for the values of total ash contents. Total ash contents in fresh flesh obtained in this study for the three fish species were close to those determined by Kayalto who studied *Tilapia nilotica* and *Arius parkii* from lake Chad. In the flesh of sun-dried or smoke-dried fish, total ash contents were higher because of water loss related to these treatments.

Protein contents: Results show that protein contents in fresh fish flesh was not significantly different from one species to another. Values obtained varied from 18.81±1.55-21.23±1.50 g/100 g *Arius parkii* and *Silurus glanis*, respectively. These values are comparable with those of Medale who obtained an average protein content of 18.5 g/100 g for 540 fish species specimen. These researchers concluded that the very broad fish taxonomic diversity did not significantly influence the content and composition of muscular proteins. In effect, other studies revealed that muscular proteins content does not vary significantly with the age and is not influenced by the composition of fish feed (Kaushik and Luquet, 1979).

Moreover, fish from Lagdo exhibit protein contents quite similar to those of sheep meat (17.2 g/100 g), cow meat (19.6 g/100 g) and pork (19.4 g/100 g) (Hladik and Leigh, 1993). Heat treatment, sun-drying and smoke-drying, increased protein contents. Important amounts were obtained: from 51.68±2.62-75.72±3.66 g/100 g with the highest value always recorded for smoke-dried products. The increase in protein contents may be due to product dehydration which concentrated proteins, thus increasing the nutritional value of Lagdo fish. Similar results were obtained by Thot and Pothast (1984).

Fats contents: Fresh fish flesh appeared to be relatively low in fats. Modest concentrations were obtained and varied between 0.57±0.01 and 1.51±0.03 g/100 g for *Tilapia nilotica* and *Silurus glanis*, respectively. Considering their fats contents, the three studied species could be considered as thin fish so as cod or haddock which fats contents is <1%. These values are slightly raised by sun-drying and smoke-drying.

The greatest increase was observed on the sun-dried flesh of *Arius parkii* (3.31±0.38 g/100 g). The low increase in fats contents could be explained by possible losses during various heat treatments. Furthermore, studies revealed that lipid contents fluctuate considerably with age, feed and sexual cycle of fish.

Thio-Barbituric Acid Reactive Substances (TBARS): The TBARS indexes are expressed in mg of Malonaldehyde per kg of raw material. In the fresh fish flesh, these indexes varied from 0.05±0.01-0.18±0.05 for *Tilapia nilotica* and *Arius parkii*, respectively. Smoke-dried fish flesh contained between 0.41±0.01 and 0.96±0.26 for *Arius parkii* and *Silurus glanis*, respectively while in sun-dried fish flesh they varied from 0.66 ± 0.07 for *Arius parkii* to 1.10±0.06 for *Silurus glanis*.

The species *Silurus glanis* which was the fleshiest and richest in lipid, exhibited the greatest TBARS indexes upon sun-drying and smoke-drying. On a nutritional point of view, a food product is considered acceptable if its TBARS index is <1 mg kg^{-1} of this product (Kezban and Nuray, 2003). Therefore only *Silurus glanis* in its two forms (sun-dried and smoke-dried) is within the threshold of acceptability with indexes of 0.96±0.26 and 1.10±0.06, respectively. For the three species studied, sun-drying induced more lipid alteration than smoke-drying. Hence, solar radiations and oxygen could have a more important pro-oxidant effect on fats than temperature.

Mineral composition: Mineral contents in fresh, sun-dried and smoke-dried fish flesh are shown in Table 3. The content in major elements (K, Mg, Na) in fresh flesh was variable from one species to another. Some values obtained were low (2.51±0.48 mg /100 g for Mg in *Tilapia nilotica*) while others were more appreciable (21.24±0.56 mg/100 g for Na in *Silurus glanis*). Appreciable amounts of trace elements were generally, detected, except for Nickel (0.02±0.00-0.20±0.06 mg/100 g) and Cadmium (0.11±0.05 with 0.39±0.02 mg/100 g). Hence, Zn (1.16±0.14-3.58±0.32 mg/100 g), Pb (0.51±0.07-2.36±0.78 mg/100 g) and Cr (91.63±4.71-428.73±3.54 mg/100 g) were the most important trace elements in fresh flesh. *Silurus glanis* had more major elements than the two other species. This may be due to its natural habitat and its feed taken from the mud.

Fresh fish from lake Lagdo contained more Ni than white fish (0.89±0.08-1.22±0.14 μg g^{-1} dry matter); brown fish (0.69±0.13-1.89±0.33 μg g^{-1} DM) and cat fish (0.97±0.13-1.95±0.33 μg g^{-1} DM) from residual water in Russia (Moiseenko and Kaudryavtsave, 2001). For zinc, Farkas *et al.* (2003) and Mansour and Sidky. (2002) determined respective contents of 14.5±2.6 and 15.2±4.36 μg g^{-1} in the flesh of *Tilapia nilotica* from lakes Balaton (Hungary) and Qarun (Egypt). These values are comparable with those of *Arius parkii* and *Tilapia nilotica* from Lagdo.

On the other hand, *Silurus glanis* from lake Lagdo and could be compared with *Dreissena polymorpha* (110 μg g^{-1} of Zn). Cadmium contents of the specimens are higher than those reported for different fish species by other researchers: 0.009 μg g^{-1} (Alam *et al.*, 2002); 0.42-0.61 μg g^{-1} (Farkas *et al.*, 2003) 0.04-0.18 μg g^{-1}(Moeller *et al.*, 2003) and 0.1-1.2 μg g^{-1} (Durali *et al.*, 2005). Similar trends were noted for Pb. In all cases traditional, fish processing impacted the mineral contents. Hence, sun-drying and smoke-drying increased significantly most analyzed elements. Smoke-drying had a greater effect on raise of most mineral than sun-drying for *Arius parkii* and *Tilapia nilotica*. However, a reverse trend was observed for Cr, Pb and Zn in *Silurus glanis*.

Mineral concentration following losses in moisture contents may explain the increases in minerals. Minerals, especially heavy metals are measured at concentrations above acceptable limits for human consumption issued by FAO (2006).

Heavy metals are probably waterborne but their accumulation through diet should not be totally neglected. Since, Lagdo lake has attracted increasing migrant populations who developed important agricultural activities around the lake, pesticides residues as well as fuel lost by old boat engines are the most probable source of water contamination.

Table 3: Mineral composition of fresh, sun-dried and smoke-dried fish flesh (mg/100 g)

	Arius parkii			*Tilapia ilotica*			*Silurus glanis*		
Treatments	Fresh	Smoke-dried	Sun-dried	Fresh	Smoke-dried	Sun-dried	Fresh	Smoke-dried	Sun-dried
K	270.32±11.13	699.56±12.37	525±6.23	280.61±6.63	789.64 ±10.25	652.14±12.25	288.65±6.75	890.74±12.45	550.55±9.17
Mg	30.10±2.13	89.13±8.25	57.36±4.38	25.10±2.48	74.98±3.81	51.65±4.290	36.41±3.31	99.87±2.61	72.45±3.98
Na	27.64±1.02	87.44±6.22	51.42±3.17	25.41±2.11	62.37±3.31	48.87±3.7	31.24±3.56	92.47±5.21	63.12±2.45
Zn	1.53±0.14	7.56 ±0.32	4.45±0.10	1.16±0.14	7.31±0.20	5.50±0.16	1.68±0.12	8.23±0.32	8.72±0.12
Ni	0.07±0.02	ND	0.11±0.01	0.02±0.00	ND	ND	0.20±0.06	0.27±0.08	ND
Cd	0.2±0.03	1.03±0.07	0.58±0.02	0.11±0.05	2.2±0.36	1.67±0.10	0.39±0.02	0.45±0.07	0.42±0.01
Pb	0.51±0.07	3.07±0.22	3.50±0.57	0.26±0.06	3.58±0.33	3.04±0.71	0.76±0.07	3.01±0.10	4.25±0.21

NB : ND : Not Detected

Table 4: Microbiological analyses

	Arius parkii			*Tilapia nilotica*			*Silurus glanis*			
Microor-ganisms	Fresh	Smoke-dried	Sun-dried	Fresh	Smoke-dried	Sun-dried	Fresh	Smoke-dried	Sun-dried	Norms*(CFU/g)
Total flora Log_{10} (CFU g^{-1})	7.53±0.68	6.41±0.60	7.43±0.70	6.03±0.88	4.99±0.95	5.36±0.33	10.30±0.76	10.26±0.89	8.44±0.55	a<10^5 b and c<10^7
Escherichia coli Log_{10} (CFU g^{-1})	4.20±0.90	4.26±0.78	4.36±0.53	5.58±0.70	ND	4.11±0.30	7.40±0.57	7.28±0.94	ND	a<20 b and c<10
Staphylococcus aureus Log_{10} (CFU g^{-1})	4.90±0.71	ND	4.08±0.56	5.13±0.47	4.04±0.81	4.08±0.65	5.15±0.97	3.95±0.42	ND	a, b and c = 0
Moulds Log_{10} (CFU g^{-1})	ND	5.25±0.76	4.48±0.6	ND	4.61±0.42	4.34±0.85	ND	ND	3.60±0.40	a = 0 b = 50 c = 100
Fecal Strept-ococci Log_{10} (CFU g^{-1})	ND	ND	3.20±0.84	ND	ND	ND	4.41±0.77	ND	ND	a = 10 b and c = 1
Sulfite-reducing C.	p	p	p	p	p	p	p	p	p	a, b and c = 0

NB : * = AFNOR, 2007 ; CFU/g = Colonies Forming Units/gram p = present ; a = fresh fish ; b = smoke fish ; c = dried fish ; sulfite-reducing C. = sulfite-reducing Clostridia. ND = Not Detected

Microbiological quality: Results of microorganisms screening are shown in Table 4. Total flora of fresh fish (in Log_{10}(CFU)) varied from 6.03±0.88-10.30±0.76 for *Tilapia nilotica* and *Silurus glanis*, respectively. In all fresh samples, the microbial population is more important than recommended by AFNOR norms. This important microbial load is indicative of possible contamination. This observation is corroborated by analyses of pathogens and spoilage flora in fresh fish flesh. *Escherichia coli*, *Staphylococcus aureus*, fecal streptococci and sulfite-reducing costridia are detected in worrying concentrations.

It is well known that these pathogens are associated with food toxiinfections are indicators on very poor hygienic quality. These bacteria are probably from soil, human and animal origin and have contaminated Lake Lagdo water. Sun-drying and smoke-drying reduced microbial loads in fish flesh but did noteliminate completely contaminant in most samples. However in some cases, *E. coli*, *S. aureus* and enterococci were totally absent in smoke-dried samples of *Arius parkii* and *Silurus glanis*.

Cooking and drying employed by this preservation method could explain the total destruction of these heat sensitive bacteria. On the contrary, sulfite-reducing Clostridia are always detected in fresh, sun-dried and smoke-dried samples.

Clostridia are thermotolerant spore forming bacteria which resist to high temperature. It can be assumed that the heat treatment in both methods was not sufficient to destroy these germs or their spores.

The results showed that moulds were not detected in fresh fish samples. These fungi generally, prefer substrate with low water activity and usually very on dry samples. This probably explains why sun-dried and smoke-dried fish flesh contained moulds to levels higher than admitted norms. The water activity in dried products is low and in favor moulds which spore are spread by air since, fish are exposed to ambient atmosphere.

CONCLUSION

Traditional fish processing around Lagdo lake produce cheap protein sources for poor populations. However, the present study shows that fish products accumulate minerals, especially heavy metals to levels exceeding most limits by health organizations and countries directives. Similarly, microbial contamination by pathogens may be considered as an important warning signal for human consumption. Therefore, important measures need to be taken to train local populations in hygienic practices as well as in controlled use of agriculture inputs.

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