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Effects of two smoking and storage methods on the sensory and bromatological quality of *Ilisha africana* (Bloch, 1795)

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Abstract
This study aimed at assessing the effects of two smoking and storage methods on the sensory and bromatological qualities of *I. africana*. The sensory analysis revealed a total mean score of 4.40 ± 1.37 for improved smoked fish against 7.33 ± 0.74 for the traditional smoked ones. Proteins, lipids, and ashes contents were 55.10 ± 0.70%, 13.43 ± 0.08% and 11.14 ± 0.98% respectively for the improved smoking method against 37.53 ± 0.94%, 12.62 ± 0.50% and 10.77 ± 0.06% for the traditional method. Bromatological parameters progressively reduced due to alteration and humidity. Sensory and bromatological qualities varied significantly (p <0.05) with smocking and storage method. This study showed that improved smoking and cooled storage have positive influence on the acceptability, shelf life and nutrition of smoked fish.

Keywords: Smoking, storage, sensory quality, bromatological quality, *I. africana*

1. Introduction
Fishery resources are foodstuffs of high nutritional value and are important part of healthy diet. Indeed, it contributes to food security and the reduction of non-transmitted diseases (Manz koule *et al*., 2020; Nchoutpouen *et al*., 2020; OMS, 2011) [1-3]. Fish is considered as a valuable source of protein, minerals and essential fatty acids for the human diet (Banda-Nyirenda *et al*., 2009) [4]. We can therefore understand the interest in this commodity whose production and global consumption has grown steadily since the 1960s (FAO, 2018) [5]. In Cameroon, fishery products count for about 19.5% of total protein requirements (INS, 2015) [6]. This percentage is increasing among the poorest layers. Its contribution to national GDP is 2.3% (MINEPIA, 2015) [7]. However, one of the major problems of this constantly evolving production is the post-capture waste of these foods.
In fact, by virtue of its texture, fish is an extremely perishable food and therefore susceptible to high post-capture losses (Kabahenda *et al*., 2009) [8]. Losses and wastage, measured from landing to consumption, are estimated at 27% of the fish landed. This represents 46.14 million tons worldwide in 2016 (FAO, 2018) [5]. Fish processing and storage needs therefore remain a topical issue in the world (Ghaly *et al*., 2010) [9]. In fact, by virtue of its texture, fish is an extremely perishable food and therefore susceptible to high post-capture losses (Kabahenda *et al*., 2009) [8]. Losses and wastage, measured from landing to consumption, are estimated at 27% of the fish landed. This represents 46.14 million tons worldwide in 2016 (FAO, 2018) [5]. Fish processing and storage needs therefore remain a topical issue in the world. Thus, in Cameroon, several methods exist to solve this problem of waste, including smoking, salting, drying, refrigeration and freezing (Hanquiez *et al*., 2009) [10]. Smoking is predominantly the most used method due to the simplicity of the procedure, taste, flavor, texture and also consumer preference (Daramola *et al*., 2007) [11].

However, these processing and preservation techniques are likely to affect their sensory and nutritional qualities. These include their macronutrient composition during the dehydration phenomenon which is accompanied by rupture of membranes due to heat treatment during smoking (Akinola *et al*., 2006) [12]. Smoking and storage processes seem to affect the quality of fish products unevenly. Various versions of artisanal fish smoking stoves have been developed and tested in several fishing communities. These include canister ovens, Altona, Parpaing, Chorkor etc.

Previous studies showed that processing affects sensory and nutritional qualities of transformed fish. These include their macronutrients composition during the dehydration (Omoruyi *et al*., 2017) [13]. Quality of smoking fish also depends on the material used in this process (Bouzgarroul *et al*., 2014) [14].

Ilisha africana is a member of Clupeideae family and is an economically important fish species found along the littoral coast of Cameroon. Because of its good flavor and occurrence of many bones, this fish species is mainly marketed in the smoked form. Study of biochemical quality is of importance for consumers and producers. However, there is limited information on its shelf life and its nutritional quality after smoking. The objective of this study was to assess the effects of improved and traditional smoking and the storage temperature on the sensory and bromatological qualities of *I. africana.*

2. Materials and methods

2.1 Sample preparation and storage condition

Fresh fish was bought at the fishing port of Douala as soon as the fishermen returned from the sea. After purchase, the fish were transported to the laboratory in a cooler containing ice at a fish/ice ratio of 1/2. Once at the laboratory, fish were rinsed with distilled water and divided intro two groups. Group 1 were used for the improved smoking and group 2 for the traditional smoking. Sensory and biochemical analysis were carried out every 7 days and this for 28 days

2.2. Smoking process

Fish were entirely smoked. The smoking temperature generated was measured using an industrial thermometer branded Bioblock (76 MM IMM). Mangrove wood was used as fuel because of its availability on smoking sites. Smoking procedure was conducted as followed:

- Pre-cooking: fish are placed in a smokehouse for 2h 30 at 40 °C;
- Cooking: the fire was accentuated at a temperature varying between 80 and 90 °C for 8 hours;
- Drying: the temperature was lowered to 50° - 60°C for 2 hours.

2.3. Improved smoking oven

The Altona oven was used for this experiment. It consists of two structures : an exterior brickwork structure to improve energy efficiency and a metal structure to hold removable hurdles. Fish were put on the different racks. The oven offers good possibilities for storing and re-smoking large amount of processed products without having to handle the fish (FODESA, 2013) [15].

2.4. Half-barrel smoking oven

The model used here is a circular sheet metal oven made from a 220-liter metal drum. It has an internal diameter of 80 cm and 70 cm height. Hurdles are made with a metal mesh. This oven makes it possible to reduce the consumption of wood but does not allow smoking a large quantity of fish.

2.5. Sensory analyzes of smoked fish

This analysis was carried out according to the quality index method described by MINEPIA (2015) [7]. The panel was made of 6 regular assessors as described by Ndrianaivo *et al*., (2016) [16]; including 3 inspectors of animal industries from the Ministry of Livestock, Fisheries and Animal Industries and 3 technicians of processing and quality control of fishery products. The assessment of smoked fish was focused on the external appearance (shine, stain, presence of insects), consistency (firmness), touch (dry / moist), smell (pleasant) and color of the flesh (homogeneous). Each of the five evaluation criteria has a maximum score of four points for poor quality and zero point for excellent quality. An average score on 20 points allowed to have, weekly, a general idea of the level of alteration of the smoked fish according to the smoking and storage methods as follows: 0-4 = Excellent; 4-8 = Very good; 8-12 = good; 12-16 = Poor and 16-20 = deteriorated. The acceptance level is given for a general mean score less than 16 as described by Omoruyi *et al*., (2017) [13].

2.6. Analysis of bromatological parameters.

Water, proteins, lipids and ashes contents was determined as described by AOAC (1990) [17]. The carbohydrate contents were obtained from to the following formula:

% Carbohydrates = Dry matter -% Proteins –% Fat -% Ash

The average value of energy was calculated using the Atwater general factor system includes energy values of 4 kcal per gram (kcal/g) for protein, 4kcal/g for carbohydrates and 9 kcal/g for fat.

AE = (4 x QCarb + (9 x QFat) + (4 x QProt)

AE : Average Energie ; Q : Quantity ; Carb : Carbohydrate ; Prot : Protein

2.7 Statistical analysis

Data were analyzed using Statgraphics Centurion software version 17.1.8. Quantitative data were expressed as means ± standard deviation (M ± ES). One-factor ordered analysis of variance (ANOVA) was used to study the effect of the processing method on fish parameters. Significant level was set at $p<0.05$.

3. Results

3.1. Effects of smoking and storage methods on the sensory quality of *I. Africana*

Results of the sensory mesasurements are shown in table 1. Mean values of sensory quality of improved smoked fish are less than those of traditionnal smoked ones. Values increased with time and are independant of storage methods.

Table 1: Changes sensory quality with smoking and storage method

Smoking/Storage.	Day 0	Day 7	Day 14	Day 21	Day 28
IS CT	4.4 ± 0.43 ^{a}	5.06 ± 0.74 ^{a}	6.2 ± 0.74 ^{ab}	7.33 ± 0.86 ^{b}	9.06 ± 0.54 ^{c}
TS CT	7.33 ± 0.74 ^{b}	8.8 ± 0.43 ^{c}	9.86 ± 0.41 ^{c}	11.86 ± 0.60 ^{d}	14.26 ± 0.96 ^{g}
IS RT	4.4 ± 0.43 ^{a}	5.73 ± 0.54 ^{a}	6.46 ± 0.30 ^{ab}	9.53 ± 1.14 ^{c}	16.66 ± 0.70 ^{f}
TS RT	7.33 ± 0.74 ^{b}	9.06 ± 0.70 ^{c}	12.4 ± 0.66 ^{d}	18.33 ± 0.64 ^{e}	20.00 ± 0.00 ^{h}

IS: Improved smoking; TS: Traditional smoking; CT: Cooled temperature; RT: Room temperature. The values are expressed as means ± standard deviation. Data with the same subscript in the same column are not significantly different at $p<0.05$.

3.2. Effects of smoking and storage methods on the variation of water contents

Changes in water contents in table 2 show significant differences (p<0.05) between the water contents of fish smoked by improved smoking and those smoked using traditional method. Water contents increased with time.

Table 2: Variation of water content with smoking and storage method

Smoking/Storage.	Day 0	Day 7	Day 14	Day 21	Day 28
IS CT	16.30 ± 0.10 [a]	17.68 ± 0.29 [c]	20.12 ± 0.62 [d]	22.59 ± 0.32 [j]	27.00 ± 0.26 [k]
TS CT	36.22 ± 0.26 [b]	40.37 ± 0.81 [e]	44.62 ± 0.28 [h]	50.07 ± 0.42 [i]	54.23 ± 0.12 [l]
IS RT	16.30 ± 0.10 [a]	20.12 ± 0.28 [d]	21.77 ± 0.47 [g]	27.67 ± 0.77 [k]	Deteriorated
TS RT	36.22 ± 0.26 [b]	41.98 ± 0.15 [f]	50.68 ± 0.18 [i]	Deteriorated	Deteriorated

IS: Improved smoking; TS: Traditional smoking; CT: Cooled temperature; RT: Room temperature. Values are expressed as mean ± standard deviation. Data with the same subscript in the same column are not significantly different at p<0.05.

3.3. Effects of smoking and storage methods on lipid, protein and carbohydrate contents

The variation in lipid, protein and carbohydrate contents with time is presented in table 3. There is no significant difference (p> 0.05) in lipid contents between improved and traditional smoking. Significant differences (p<0.05) however appear during the storage time.

There's a significant difference (p<0.05) on protein and carbohydrate contents between smoking method and storage method.

Table 3: Variation in lipid, protein and carbohydrate contents with smoking and storage method

Smoking/ Storage	Macronutrients	Day 0	Day 7	Day 14	Day 21	Day 28
IS TC	Lipid	13.43 ± 0.08 [a]	12.63 ± 0.97 [ab]	11.63 ± 0.70 [cd]	10.71 ± 0.23[efh]	9.07 ± 0.88 [h]
	Protein	55.10 ± 0.70 [a]	55.02 ± 0.42 [a]	54.66 ± 0.55 [ac]	54.69 ± 0.39 [bd]	52.43 ± 0.40 [i]
	Carbohydrate	4.02 ± 0.63 [a]	3.99 ± 0.64 [ab]	3.88 ± 0.56 [ab]	3.56 ± 0.92 [abc]	3.40 ± 0.43 [abcd]
TS TC	Lipid	12.62 ±0.50 [ab]	11.98 ± 0.35 [bc]	11.07 ± 0.60 [de]	9.65 ± 0.05 [gh]	9.69 ± 0.20 [i]
	Protein	37.53 ± 0.94 [b]	34.27 ± 0.95 [e]	31.02 ± 0.45 [f]	29.11 ± 0.17 [h]	25.82 ± 0.71 [j]
	Carbohydrate	3.06 ± 0.53 [bcde]	2.70 ± 0.47 [cde]	2.60 ± 0.86 [de]	2.58 ± 0.40 [de]	2.45 ± 0.46 [e]
IS RT	Lipid	13.43 ± 0.08 [a]	12.42 ± 0.55 [bc]	11.32 ± 0.19 [de]	10.61 ± 0.65 [ef]	Deteriorated
	Protein	55.10 ± 0.70 [a]	54.00 ± 0.80 [cd]	53.47 ± 0.59 [d]	51.25 ± 0.72 [i]	Deteriorated
	Carbohydrate	4.02 ± 0.63 [a]	3.06 ± 0.55 [bcde]	2.74 ±0.44 [cde]	2.73 ± 0.24 [cde]	Deteriorated
TS RT	Lipid	12.62 ±0.50 [ab]	11.65 ± 0.48 [cd]	10.15 ± 0.04[fg]	Deteriorated	Deteriorated
	Protein	37.53 ± 0.94 [b]	33.40 ± 0.54 [e]	28.36 ± 0.21 [g]	Deteriorated	Deteriorated
	Carbohydrate	3.06 ± 0.53 [bcde]	2.56 ± 0.46 [de]	2.50 ± 0.72 [de]	Deteriorated	Deteriorated

IS: Improved smoking; TS: Traditional smoking; CT: Cooled temperature; RT: Room temperature. Values are expressed as mean ± standard deviation. Data with the same subscript (for the same macronutrients) in the same column are not significantly different at p<0.05.

3.4. Effects of smoking and storage methods on the variation of ash contents

The variation of the ash contents is presented in table 5 shows no significant difference (p>0.05) between improved and traditional smoking.

Table 4: Weekly variation of ash content depending on the smoking and storage method

Smoking/Storage.	Day 0	Day 7	Day 14	Day 21	Day 28
IS CT	11.14 ± 0.98 [a]	10.67 ± 0.42 [a]	10.58 ±0.80 [a]	8.43 ± 0.23 [c]	8.10 ±0.25 [d]
TS CT	10.77 ± 0.06 [a]	10.56±0.66 [ab]	9.69 ± 0.38 [b]	8.58 ± 0.61 [c]	7.80 ± 0.20 [e]
IS RT	11.14 ± 0.98 [a]	10.68±0.36 [ab]	10.39±0.22 [a]	8.34 ± 0.72 [c]	Deteriorated
TS RT	10.77 ± 0.06 [a]	10.40 ± 0.62 [a]	8.30 ± 0.38 [c]	Deteriorated	Deteriorated

IS: Improved smoking; TS: Traditional smoking; CT: Cooled temperature; RT: Room temperature. Values are expressed as means ± standard deviation. Data with the same subscript in the same column are not significantly different at p<0.05.

2.5. Effects of smoking and storage methods on energy

Table 5 shows the variation in fish energy with smoking method and the storage time.

Table 5: Variation of the energy content (per 100g of material) with smoking and storage temperature

Smoking/Storage.	Day 0	Day 7	Day 14	Day 21	Day 28
IS CT	357.35	349.71	338.83	329.39	304.95
TS CT	275.94	255.7	234.11	213.61	200.29
IS RT	357.35	340.02	326.72	311.41	Deteriorated
TS RT	275.94	248.69	214.79	Deteriorated	Deteriorated

IS: Improved smoking; TS: Traditional smoking; CT: Cooled temperature; RT: Room temperature. The values are expressed as mean ± standard deviation. Data with the same subscript in the same column are not significantly different at p<0.05.

3. Discussion

Quality of smoked fish is under influence of many factors such as physical properties of the fish flesh, maturity, age, sex, season, type of wood used, composition of the smoked, temperature, humidity, density of smoke (Oyero *et al*., 2012) [18]. According to Karim *et al*., (2007) [19], flavor is an

important factor for consumer satisfaction. The score at days 0, 7, 14, 21 and 28 showed that improved smoking leads to a better organoleptic quality because of the color and texture of fish. This may be the result of a better control of time and temperature parameters during the improved smoking. These parameters influence color and dehydration which is too low with traditional smoking leading to a soft texture of fish. Van Den Berghen *et al*. (1988) [20] also found a decreased of water content in fish smoked by improved method than by traditional one.

Traditionnal smoked fish stored at room temperature deteriorates more easily before 21 days (18.33 ± 0.64) against 28 days (16.66 ± 0.70) for improve smoking according to the acceptability limits given by Omoruyi *et al*. (2017) [13]. Important reduction of water contents by improved smoking improve preserve fish from degradation. There is frequent change in water content during storage and this phenomenon is weather dependent. Water content and degradation of smoke fish increase with the level of moisture (Ndrianaivo *et al*., 2016) [16].

Thus, on the 28th day, only the refrigerated fish maintained an acceptable sensory quality. Kumolu-Johnson *et al*. (2010) [21] corroborated this result by showing progressive deterioration and rejection of the product on the 28th day with *Clarias gariepinus*. There was significant difference (p<0.05) between improved and traditional smoked fish and between those stored at ambient and cooled temperature (table 2). Water content of the same improved smoked fish is close to that obtained by Adeyeye *et al.,* (2015) [22] (15.18%). According to Adebowale *et al*. (2008) [23], burning reduces the water content of fish up to 15.56%, while smoking reduces it to about 35.03%.

At Day 0 there were no significant difference (p>0.05) in lipid contents between improved and traditional smoke fish. Significant difference (p <0.05) appeared on day 14 between samples stored at room temperature and on the 28th day for those stored at refrigeration temperature. Lipid contents of *I. africana* ranged between 9.07 ± 0.88 and 13.43 ± 0.88. Similar values were obtained in the same species by Adeyeye *et al.*, (2015) [22]. However, the values seem to be underestimated. Bou M'Handi *et al.*, (2015) [24] found for smoked mackerel, loss of lipids up to 35% due to fat oxidation. Lipid contents seemed to decrease during storage probably because of gradual reabsorption of air humidity which affects nutrients concentration.

The protein contents of traditionally smoked fish are below the range of the values (52.13 - 60.22%) obtained by Adeyeye *et al.*, (2015) [22]. Low values of protein contents observed for traditional smoking method could be due to poor dehydration or denaturation which occurred because of noncontrolled smoking temperatures (Chabi *et al*., 2014) [25]. But, protein contents of fish smoked by the improved smoking method felt in the normal range found in previous works. So, there was significant differences (p<0.05) in protein contents between traditionally and improved smoked fish and also between fish stored at room temperature and those refrigerated. According to Bandara *et al.*, (2001) [26], the chemical composition of fish could also vary according to diet, migrations and others physiological phenomenons.

The two smoking methods used have no effect on ash content. According to AOAC, (1990) [17], ashes are extracted at a temperature up to 450-degree C. Ude *et al.* (2017) [27] found 7.55 ± 0.19 and 7.17 ± 0.16 respectively for improved and traditional smoking of the same fish species from the Nigerian's coasts. These differences would be due to the state of the raw material because they have used frozen fish rather than smoked ones. According to Bou M'Handi *et al.* (2015) [24], during frozen, fish gradually loose its nutritional qualities as a function of time and temperature. The high ash contents in smoked *I. africana* is an indication of important mineral contain in the flour as previously mentioned by others (Ahmed *et al*., 2011) [28].

The carbohydrate contents of the fish studied are low. Ude *et al*. (2017) [27] found for the same species 7.99 ± 0.44 and 4.73 ± 0.14 respectively for improved and traditional smoking. Physiological state of the fish and/or heat treatments can explain that founding (Combe, 2003) [29]. There was significant difference (p<0.05) between improved and the traditional smoked fish one at Day 0.

Loss of water during improved smoking is linked to the increase quantity of energy obtained. According to Opoye *et al.* (1990) [30], Smoked fish concentrates its nutrients after losing water. This makes improved smoked fish more rich in energy than traditionally smoked one at equal mass. Energy decreases over time due to the gradual reabsorption of moisture.

Conclusion

The sensory and bromatological quality of *I. africana* varies with type of smoking and storage method. Fish smoked by improved method has good sensory and bromatological qualities irrespective to the conditions of storage. Improved smoked fish are more accepted by consumers for their appearance, consistency, feel, odor and color. Sensory and nutritional assessment revealed that improved smoking with refrigeration allows better preservation of the macronutrients of *I. africana*. Improving smoking by using oven is therefore more nutritionally suitable for processing and preservation of this fish.

Conflicts of interest

The authors declare that they have no competing interests related to this article.

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