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Influence of processing and preservation processes on technological and organoleptic qualities of *Coptodon guineensis* and *Sarotherodon melanotheron* in south Benin

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Abstract

Fish is one of the most important protein sources in Benin. Inappropriate processing and preservation processes could deteriorate fish quality traits. The study aims to evaluate the effect of processing and preservation processes on the technological and organoleptic qualities of fish in south Benin. Thus, 86 fish processors and wholesalers were surveyed. In total 120 samples of *S. melanotheron* and *C. guineensis* were randomly collected for the technological and organoleptic quality evaluation. Technological mesures (yields, pH, and water content) and sensory tests (texture, color, and freshness state) were performed to evaluate fillet quality. The frying was performed through the following stages: oil heating, flour mixture with fish and putting the mixed fish with flour in oil. The smoking is performed through the following stages: soft fires and fire with smoke. *S. melanotheron* presented higher ($P<0.05$) eviscerated weight (113.33g) than *C. guineensis* (85.34g). *C. guineensis* presented higher ($P<0.05$) fillet yield and pH (6h, 24h and 48h) than *S. melanotheron*. As for the organoleptic quality, the yellow index, lightness and chroma were higher ($P<0.001$) in *S. melanotheron* than in *C. guineensis*. The lightness of fried and smoked *S. melanotheron* was higher ($P<0.05$) than that of fried and smoked *C. guineensis*. The texture was similar between the treatments ($P>0.05$). The tenderness, juiciness, flavor and the consumer global acceptance mark were not different between the fish and between the cooking modes. The optimization of fish processing and preservation processes will guarantee a better technological and organoleptic quality of fish to the consumer.

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Introduction

Fish are perishable foodstuffs (ANSES, 2015) and are a protein source for developing countries, especially Benin. In order to eat them long time after the capture, it is necessary to preserve or transform them (ANSES, 2010). Indeed, in Benin, a significant proportion of continental watercourses fish production is marketed fresh. The rest undergoes artisanal processing (smoking, frying, salting-drying) (FAO, 2016). Thus, 10% of tilapia is smoked for preservation, 5% is fried and part of fried tilapia is exported to Togo (Rurangwa *et al.*, 2014). The processing goal is to preserve and/or improve certain qualities of the product: fish sanitary, technological, nutritional and organoleptic qualities (Choubert, 2010). However, the physical constraints undergone by fish during their capture and along sorting, packaging, storage and processing operations are decisive in their nutritional, organoleptic, microbiological and technological quality. Moreover, inappropriate processing and preservation processes could deteriorate fish quality traits. The control of technological and sensory qualities parameters is usefull to satisfy consummers expectations and to be competitive on the market.

In a recent study, Assogba and Youssao (2017) evaluated the effect of processing and preservation processes on the microbiological quality of *Coptodon guineensis* and *Sarotherodon melanotheron* in south Benin. This study identified spoilage germs and they could negatively influence the technological and organoleptic quality of fish.Several studies have also been carried out on the processing processes improvement and their reducing effects on fish sanitary quality (Wabi 2010, Degnon *et al.*, 2012, 2013, Chabi *et al.*, 2014, Kpodekon *et al.* 2014).However, there was no studyon the impact of processing and preservation processes on the technological and organoleptic quality of fish. To meet the requirements of processed fish market and those of consumers, it is important to study the impact of these processing and preservation processes on the technological and organoleptic qualities. The purpose of this study was therefore to evaluate the effect of processing and preservation processes (frying and smoking) on the technological and organoleptic qualities of *Coptodon guineensis* (Günther, 1862) and *Sarotherodon melanotheron* (Rüppell, 1852) in south Benin. These two species were chosen because of their numerical abundance and their socio-economic importance in south Benin (Youssao *et al.*, 2011, Amoussou *et al.*, 2016).

Materials and methods

Study area

Data collection on the effect of processing and preservation processes on the technological and organoleptic quality of *C. guineensis* and *S. melanotheron* was performed from June to December 2014 at the embankment and in the kpota market in Abomey Calavi Township. This Township is located at 12 meters of altitude between 6° 26' North latitude and 2° 21' East longitude. It is in the Atlantic Department, South of Benin and bounded to the North by the Township of Zè, to the South by the Atlantic Ocean, to the East by the Township of Sô-Ava and Cotonou, and to the West by the Townships of Tori-Bossito and Ouidah. The climate is of the subequatorial type characterized by two rainy seasons and two dry seasons. The Township has two bodies of water, Nokoué Lake and Cotonou Lagoon, a sea front juxtaposed to Cotonou Lagoon, marshes, streams and swamps. These bodies of water offer the Township a very lively artisanal fishing activity. The township has also several local markets (Kpota, Glodjigbé, Akassato, Zinvié and Zè). The Kpota market has anembankment where caught fish from the Nokoué Lake are regularly sold. In this market fish are marketed whole or processed. Fish processing is of artisanal type. Once samples collected, technological and organoleptic parameters were measured at the Laboratory of Animal Biotechnology and Meat Technology of the Department of Animal Production and Health of the Polytechnic School of Abomey-Calavi of the University of Abomey-Calavi (Benin).

Sampling

Surveys were carried out at the embankment and in the Kpota market in Abomey-Calavi on two fish species (*C. guineensis* and *S. melanotheron*). A total of 86 persons were surveyed, including 55 fish wholesalers at the embankment and 31 in the market. The interviews were done based on a questionnaire. During the survey, data relating to the actors status (fishers, fish wholesalers and processors), catching (species fished, biomass), processing and preservation, equipment and personal hygiene have been collected. The two fish species were those caught by the fishers in Nokoué Lake and in the "acadja" breeding systems installed over this lake. They feed on phytoplankton and zooplankton.

A total of 120 fish were sampled including 40 *S. melanotheron* of which 10 whole *S. melanotheron* at the embankment (2 males and 8 females) and 10 whole *S. melanotheron* in the market (2 males and 8 females), 10 pre-processed *S. melanotheron* (2 males and 8 females) at the embankment and 10 pre-processed *S. melanotheron* (4 males and 6 females) in the market, and 40 *C. guineensis* of which 10 whole *C. guineensis* at the bank (6 males and 4 females) and 10 whole *C. guineensis* in the market (4 males and 6 females), 10 pre-processed *C. guineensis* (4 males and 6 females) at the embankment and 10 pre-processed *C. guineensis* (4 males and 6 females) in the market. Then, 20 fried and smoked *S. melanotheron* were randomly sampled including 10 fried *S. melanotheron* (8 males and 2 females) and 10 smoked *S. melanotheron* (4 males and 6 females) in the market, and 20 fried and smoked *C. guineensis* were randomly collected including 10 fried *C. guineensis* (8 males and 2 females) and 10 smoked *C. guineensis* (8 males and 2 females) in the market from the women processors at selling. The sampled fish were transported to the laboratory in sterile Stomacher bags put in cooler at 4°C as prescribed by ISO 7218: 2007.

Technological measures

Then, the weights of fish, fillets after evisceration, beheading, scaling and filleting were taken. The remaining was determined by a difference between the fish whole weight and the weight of beheaded and eviscerated fish. These weights were used to determine fish yield (eviscerated weight / total weight of whole fish) and fillet yield (fillet weight / whole fish weight). The fish water content was determined according to the Codex Stan 167-1989 standard. The pH was measured in the fish fillet at 6 hours, 24 hours and 48 hours after fish sampling using a pH meter (Hanna HI 99161, Instruments R, Italy) provided with a combined electrode.

Sensory measures

The freshness state was evaluated basedon the organoleptic evaluation chart of the freshness state of the Regulation 103/76 / EEC. The loss of the initial freshness characteristics and the appearance of detectable decomposition phenomena by the human senses were appreciated. The different observation points were related to the fish external and internal examination which covers the skin appearance, its pigmentation and mucus, the eye appearance, its hue and curvature, the gills, hue and odor, flesh appearance, the state of the abdominal wall, abdominal cavity, spine, peritoneum and organs (liver, kidney, spleen, intestine, heart). Each of the points received a rating called "spoilage index", from 3 to 0, ranging from the freshest to the most spoiled. The ratings average of all the elements enables the evaluation of the freshness degree of the whole fish. When the ratings average is greater than or equal to 2.7, the fish quality is "Extra", greater than or equal to 2 and less than 2.7, it is of the category "A", for an average greater than or equal to 1.0 and less than 2.0, the quality is of category "B" and for an average less than 1.0, the fish quality is of the category "C" and the batch is to be withdrawn from the consumption.

Fish fillets have been prepared for organoleptic and physical tests in accordance with Codex Alimentarius guidelines for organoleptic evaluation of fish, mollusc and crustaceans in laboratory CAC/GL 31-1999. Pieces of fillets of 200 g from each species and locality were appreciated by a jury of 10 people without any prior training, after cooking with water or frying with groundnut oil, all without seasoning. Marks were then given by the jury to each tested parameter (juiciness, tenderness and favor). The tenderness, juiciness and flavor's intensity marks ranged from 1 to 5. For tenderness, 1 corresponds to very hard, 2 to hard, 3 to acceptable, 4 to tender and the 5to very tender. As for the juiciness, 1 corresponds to very dry, 2 to dry, 3 to acceptable, 4 to soft and 5 to very soft. Finally, the flavor's intensity was very low (1), low (2), acceptable (3), high (4) and very high (5).

Finally, the color and texture measurements were performed using respectively a colorimeter (Konica Minolta CR-400 INC) and a Texture Analyzer (LLYOD instruments) with 5 repetitions per sample. The color was determined according to the CIE L* a* b* system and was taken at the internal face of whole, eviscerated, smoked and fried fish fillets. The red index (a *), the yellow index (b *) and the lightness (L) were measured and the chroma calculated as $C = (a^{*2} + b^{*2})^{1/2}$. As for the texture, it was evaluated on fillets cuts of 1x1x5 cm (thickness x width x length) by the shear force expressed in Newton.

Statistical analysis

The Statistical Analysis System software (SAS, 2013) was used for the statistical analysis. Survey data was stripped, encoded and analyzed. The frequencies were calculated using the *Proc freq* procedure. They were compared by the Chi-Square test and by the bilateral Z-test. The Generalized Linear Model Procedure was used for the variance analysis. The factors used in the ANOVA model were: species, location, sex and processing mode. The F-test was used to determine the significance of each effect of the model on the technological characteristics of the fish flesh and the least-mean-squares were estimated and compared paired by the t-test. Correlations between the different variables were determined by fish species using the *Proc corr* procedure (SAS, 2013).

Results

Fresh fish pre-processing and processing process

The most pre-processed fish species by all fish wholesaler is Tilapia at the Kpota market and embankment. The fish were sold whole or pre-processed or processed following two modes as requested by the consumers. The fish were pre-processed by the fish wholesalers for the product better presentation or for more benefit. These fish came from fishers, retailers or fish farmers. At the Kpota embankment, 81.25% of fish wholesalers got fish to be pre-processed from retailers against 34.78% from the Kpota Market (P<0.001). The pre-processing consisted to fish washing, scaling, evisceration and rinsing (Table 1).

Table 1. Fish species used for frying, smoking and their origin.

Variables		Kpota market			Kpota bank			Significance test
		Number	Percentage	CI	Number	Percentage	CI	
Pre-processed species	*Tilapia*	23	100a	0	32	100a	0	NS
	Clarias	23	9.38a	11.92	32	0a	0	NS
	Other	23	9.38a	11.92	32	13.04a	11.67	NS
Sold type fish	Whole fish	23	28.13a	18.38	32	39.13a	16.91	NS
	Pre-processed fish	23	75a	17.70	32	73.91a	15.21	NS
	Pre-processed fish at the consumer request	23	82.61a	15.49	32	71.88a	15.58	NS
Why fish are pre-processed?	For more benefit	23	17.39a	15.49	32	15.63a	12.58	NS
	For presentation	23	73.91a	17.95	32	68.75a	16.06	NS
	Other	23	8.70a	11.52	32	3.13a	6.03	NS
Origin of pre-processed fish	Fisher	23	4.35a	8.34	32	6.25a	8.39	NS
	Retailer	23	34.78b	19.46	32	81.25a	13.52	***
	Fish farmer	23	4.35a	8.34	32	6.25a	8.39	NS
	Other	23	0	0	32	0	0	-
Pre-processing activities	Washing	23	69.57a	18.80	32	71.88a	15.58	NS
	Scaling	23	69.57a	18.80	32	71.88a	15.58	NS
	Evisceration	23	69.57a	18.80	32	71.88a	15.58	NS
	Rinsing	23	69.57a	18.80	32	71.88a	15.58	NS
	Other	23	0	0	32	3.16	6.06	-

NS : P>0.05 ; *** : P<0.001 ; CI= Confident Interval; Intra-class means of the same row followed by different letters differ significantly at the threshold of 5%.

The material and the raw material used for the frying at each processing stage were composed of: knife, basin, frying-pan, saucepan, skimmer, palm oil, groundnut oil, salt, maize flour and water.

The frying was performed through the following steps: oil heating, flour mixing with fish, putting of the mixed fish mixed with flour into the oil (Fig. 1).

As for the smoking, the material and raw material used at each stage were composed of: wood, sawdust or wood chips, charcoal, chokor kiln, wire-netting, earthen hearth and barrel hearth. Smoking was performed following these steps: soft fireand smoke fire (Fig. 1).

Variation of fish technological characteristics according to the locality, species and sex

The technological characteristics did not vary according to the localities (P>0.05).

Females have a pH24 higher (P<0.05) than males. However, no difference was observed between the pH48 of the two sexes. *S. melanotheron* had aneviscerated weight higher than *C. guineensis* (P<0.05). On the other hand, *C. guineensis* had a fillet yield and pH (6h, 24h and 48h) higher (P <0.05) than *S. melanotheron* (Table 2).

Table 2. Effect of locality, species and sex on fish technological characteristics.

Parameters	Locality				Species				Sex				Significance test		
	Embankment		Market		*S. melanotheron*		*C. guineensis*		Female		Male		Locality	Species	Sex
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE			
LW (g)	134.9a	16.78	118.8a	21.48	143.74a	23.22	109.97a	16.96	140.82a	15.38	112.89a	24.42	NS	NS	NS
EW (g)	104.67a	8.42	94a	9.04	113.33a	9.70	85.34b	8.37	109.88a	7.88	88.79a	10.13	NS	*	NS
FW (g)	67.15a	5.77	57.87a	6.19	67.09a	6.65	57.93a	5.73	69.11a	5.40	55.90a	6.94	NS	NS	NS
Remaining (g)	34.96a	8.51	25.72a	10.89	32.45a	11.77	28.24a	8.60	30.22a	7.80	30.46a	12.38	NS	NS	NS
Y (%)	76.04a	3.42	76.55a	4.38	78.54a	4.73	74.05a	3.46	80.79a	3.14	71.77a	4.98	NS	NS	NS
FY (%)	64.86a	2.00	61.63a	2.14	58.59b	2.30	67.89a	1.99	63.58a	1.87	62.89a	2.40	NS	**	NS
pH6	6.38a	0.06	6.41a	0.06	6.26b	0.07	6.53a	0.06	6.44a	0.05	6.34a	0.07	NS	**	NS
pH24	6.46a	0.04	6.41a	0.05	6.31b	0.05	6.56a	0.04	6.50a	0.04	6.36b	0.05	NS	***	*
pH48	6.50a	0.04	6.46a	0.05	6.36b	0.05	6.60a	0.04	6.55a	0.04	6.41a	0.05	NS	***	NS
WC (%)	77.92a	1.21	75.25a	1.30	75.43a	1.39	77.73a	1.20	77.51a	1.13	75.65a	1.45	NS	NS	NS

WC: Water content; NS: P>0.05. *: P<0.05; **: P<0.01; ***: P<0.001; FY: Fillet yield; Y: Fish yield; FW: Fillet weight; LW: Live weight: EW: Eviscerated weight. SE: Standard Error; pHi: Hydrogen potential at i hours. Intra-class means of the same row followed by different letters differ significantly at the threshold of 5%.

Correlations between the technological characteristics of Sarotherodon melanotheron and Coptodon guineensis

In *C. guineensis*, live weight was positively correlated with eviscerated weight (P<0.001, r = 0.847) and fillets weight (P<0.05, r = 0.861). However, a negative correlation was observed between pH6 and live weight (P<0.01, r = -0.800).

Eviscerated weight was proportional to fillet weight and a positive correlation was found between fillet weight and eviscerated weight (P<0.001, r = 0.927). The yield was negatively correlated with the rest of the fish after treatment (P<0.05, r = -0.703). A positive correlation was observed between pH 6, 24 and 48h (Table 3).

The correlations between live weight, eviscerated weight, and fillet weight of *S. melanotheron* were more significant (P<0.001, r> 0.890) than those in *C. guineensis* (Table 3).

The yield was negatively correlated with the rest of the fish after treatment (P<0.001, r = -0.900) and the pH values were positively correlated with each other.

Table 3. Correlations between the technological characteristics of *C. guineensis* (above the diagonal) and *S. melanotheron* (below the diagonal).

Variables	LW	EW	FW	Remaining	Y	FY	pH6	pH24	pH48	WC
LW	1	0.847**	0.861**	0.637*	0.066^{NS}	-0.013^{NS}	-0.800**	-0.563^{NS}	-0.250^{NS}	0.256^{NS}
EW	0.891***	1	0.927***	0.130^{NS}	0.569^{NS}	0.007^{NS}	-0.499*	-0.333^{NS}	-0.016^{NS}	0.038^{NS}
FW	0.901***	0.922***	1	0.468^{NS}	0.242^{NS}	0.365^{NS}	-0.387^{NS}	-0.219^{NS}	0.093^{NS}	0.055^{NS}
Remaining	0.831**	0.490^{NS}	0.547^{NS}	1	-0.703*	0.464^{NS}	-0.485^{NS}	-0.425^{NS}	-0.209^{NS}	0.027^{NS}
Y	0.567**	-0.155^{NS}	-0.210^{NS}	-0.90***	1	-0.461^{NS}	-0.018^{NS}	0.223^{NS}	0.164^{NS}	0.232^{NS}
FY	0.461^{NS}	0.110^{NS}	0.473*	0.391^{NS}	-0.235^{NS}	1	0.290^{NS}	0.257^{NS}	0.200^{NS}	0.011^{NS}
pH6	-0.447^{NS}	-0.226^{NS}	-0.245^{NS}	-0.177^{NS}	0.078^{NS}	-0.069^{NS}	1	0.483*	0.146^{NS}	0.016^{NS}
pH24	-0.196^{NS}	0.050^{NS}	-0.061^{NS}	-0.123^{NS}	0.100^{NS}	-0.212^{NS}	0.720***	1	0.692***	-0.358^{NS}
pH48	-0.162^{NS}	-0.060^{NS}	-0.152^{NS}	-0.073^{NS}	0.014^{NS}	-0.201^{NS}	0.498^{NS}	0.279^{NS}	1	-0.384^{NS}
WC	0.465^{NS}	0.285^{NS}	0.284^{NS}	0.396^{NS}	-0.245^{NS}	0.082^{NS}	0.736***	0.323^{NS}	0.362^{NS}	1

LW: Live Weight: EW: Eviscerated Weight; FW: Fillet weight; Y: Fish yield; FY: Fillet yield; pHi: Hydrogen potential at I hours; WC: Water content; NS: P> 0.05; *: P <0.05; **: P <0.01; ***: P <0.001.

Organoleptic qualities

Freshness state and quality index

The freshness state of the skin, the eye, the gills, the wall and the abdominal cavity, the spine, the heart, the liver, the intestine, the peritoneum and the abdominal wall of *S. melanotheron* was similar to that of *C. guineensis* (P>0.05) (Table 4).

Table 4. Freshness state of *S. melanotheron* and *C. guineensis*.

Parameter	*S. melanotheron*		*C. guineensis*		Significance Test
	Mean	SE	Mean	SE	
Skin	2.93a	0.10	2.83a	0.10	NS
Eye	3.00a	0.09	2.87a	0.09	NS
Gills	2.67a	0.15	2.50a	0.15	NS
Wall	3.00a	0.07	2.90a	0.07	NS
Cavity	3.00a	0.16	2.60a	0.16	NS
Spine	3.00a	0.07	2.90a	0.07	NS
Organ	3.00a	0.07	2.90a	0.07	NS
Peritoneum	2.90a	0.10	2.90a	0.10	NS
Mean	3.23a	0.11	3.07a	0.11	NS

SE: Standard error; NS: Not significant. Intra-class means of the same column followed by different letters differ significantly at the threshold of 5%.

Two quality indices were recorded in *C. guineensis:* the Extra index (90%) and the B index (10%). All the *S. melanotheron* were of Extra Index class.

Effect of locality, species and cooking mode on fish sensory characteristics

The red index, lightness, yellow index, and chroma of fish flesh didn't vary by location and sex (P>0.05) (Table 5). The yellow index, lightness, and chroma were higher in *S. melanotheron* (P<0.001) than in *C. guineensis.*

The color varied significantly according to the process. The yellow index of fried fillets (15.38) was higher than that of smoked fillets (14.45).

Similarly, the chroma of fried fillets (125.14) was higher (P<0,001) than that of smoked fillets (107.54).

On the other hand, the highest red index was obtained in pre-processed fish fillets (1.04) and was different (P<0.01) from that of smoked fillets (-0.08). However, the lightness was higher (P<0.001) in smoked fillets than in fried fillets (Table 5).

Table 5. Effect of locality, species, sex and treatments on fish color.

Variables	Locality				Species				Sex				Treatements								Significance test			
	Bank		Market		*S. mel*		*C. guin*		Female		Male		Whole		Fried		Smoked		Pre-processed		Loc	Esp	Sex	Treat
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
L*	51.63a	6.34	57.36a	12.18	56.61a	11.35	54.09b	10.22	53.45a	9.77	57.13a	11.53	52.2c	5.91	57.62b	12.76	68.72a	11.86	50.77c	6.76	NS	***	NS	***
a*	0.79a	1.84	0.71a	2.01	0.60a	1.63	0.88a	2.21	0.90a	1.68	0.59a	2.16	0.83a	1.8	0.76a	1.63	-0.08b	1.24	1.04a	2.36	NS	NS	NS	**
b*	3.25a	2.77	9.04a	6.55	7.68a	6.41	6.35b	5.88	5.28a	5.03	8.63a	6.71	3.40 a	2.79	15.38b	3.26	14.45b	2.19	2.76 a	2.26	NS	***	NS	***
Chrm	11.11a	12.98	64.54a	61.99	51.45a	63.51	40.23b	48.29	28.36a	42.05	62.19a	63.33	11.62c	13.2	125.14a	50.72	107.54b	30.39	9.66c	12.68	NS	***	NS	***

Chrm: Chroma; L*: lightness; a*: red index; b*: yellow index; S.mel: *Sarotherodon melanotheron*; C.guin: *Coptodon guineensis*; Loc: Locality; Esp: Species; Treat: Treatments; the intra-class averages of the same line followed by different letters differ significantly at the threshold of 5%; SD: Standard deviation; NS: P>0.05; *: P <0.05; **: P<0.01; ***: P<0.001.

The interactions between locality and species were not significant on color except for the red index (P<0.01) (Table 6). In *S. melanotheron*, the lightness of male fillets was similar to that of females.

On the contrary, in *C. guineensis*, male fillets had a higher lightness (P<0.001) than females (56.55 versus 49.86). In each species, the lightness varied according to the treatment method (Table 6).

The lightness of fried *S. melanotheron* (61.69) and smoked (71.83) was higher (P<0.05) than that of fried (53.55) and smoked (65.6) *C. guineensis*. No differences were observed in the lightness between the fresh fillets of whole and pre-processed fish of both species (P>0.05). The highest chroma (P<0.001) were obtained during frying in *C. guineensis* (113.15) and *S. melanotheron* (128.11) (Table 6).

Table 6. Effect of interaction between locality and species, species and sex, treatment and species on fish color.

Variation source		L*		a*		b*		Chroma	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Embankment	*S.mel*	51.36a	6.28	1.07ad	1.7	3.60a	2.57	11.73a	12.84
	C.guin	51.91a	6.46	0.48ab	1.95	2.87a	2.96	10.44a	13.24
Market	*S.mel*	59.65a	12.5	0.32a	1.54	10.04a	6.78	74.45a	69.59
	C.guin	55.19a	11.53	1.08ac	2.31	8.08a	6.22	55.12a	52.44
	Significance test	NS		**		NS		NS	
S. melanotheron	Female	55.65a	10.22	0.76a	1.59	5.75c	4.77	29.37c	41.41
	Male	58.07a	12.83	0.35ac	1.68	10.57a	7.44	84.57a	75.78
C. guineensis	Female	49.86b	7.84	1.14ab	1.8	4.52d	5.38	26.71c	43.41
	Male	56.55a	10.67	0.73a	2.42	7.40b	5.93	48.05b	49.44
	Significance test	***		NS		NS		NS	
S. melanotheron	Whole	51.68c	6.25	1.19ab	1.79	4.15d	2.52	14.03d	13.85
	Fried	61.69b	14.07	0.31bc	1.7	16.11a	3.5	137.10a	57.4
	Smoked	71.83a	7.98	-0.22c	1.0	15.9ab	1.51	128.11a	23.88
	Pre-processed	51.4c	6.39	0.57bc	1.5	2.88^{e}	2.15	7.70d	7.68
C. guineensis	Whole	52.78c	5.51	0.44bc	1.75	2.57^{e}	2.87	8.94d	12.08
	Fried	53.55c	10.00	1.22ab	1.44	14.65b	2.89	113.15b	40.76
	Smoked	65.6b	14.26	0.06c	1.46	12.99c	1.77	86.97c	20.83
	Pre-processed	50.19c	7.09	1.46a	2.88	2.65^{e}	2.37	11.43d	15.79
	Significance test	**		*		*		***	

L*: lightness; a*: red index; b*: yellow index; the intra-class means of the same column followed by different letters differ significantly at the threshold of 5%; SD: Standard deviation; NS: P>0.05; *: P<0.05; **: P<0.01; ***: P<0.001; S.mel: *Sarotherodon melanotheron*; C.guin: *Coptodon guineensis*.

As for the raw flesh texture, it didn't differ according to the locality, species and sex (P> 0.05). By contrast, the shear force (Fmax) recorded in whole *C. guineensis* (68.54 N) was higher than that of whole *S. melanotheron* (62.69N). Shear force was lower in females (70.30N) than in males (60.91N) (Table 7).

Table 7. Effect of locality, species and sex on fish flesh texture.

Variables	Locality				Species				Sex			
	Embankment		Market		*S. mel*		*C. guin*		Female		Male	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
All (mm)	13.79a	0.67	13.99a	0.64	14.63a	0.55	13.15a	0.61	12.72a	0.69	15.06a	0.67
Fmax (N)	13.99a	0.64	64.60a	3.88	62.69a	3.32	68.54a	3.66	70.30a	4.17	60.91a	4.06

SE: Standard error; F: Shear force; All: lenghtening; the intra-class means of the same line followed by the different letters differ significantly at the threshold of 5%. S.mel: *Sarotherodon melanotheron*; C.guin: *Coptodon guineensis*.

The tenderness, juiciness, flavor and global consumer acceptance were not different between *S. melanotheron* and *C. guineensis* and between cooking methods (boiling and frying). *S. melanotheron* and *C. guineensis*, fried or boiled at the Kpota market, have the same tenderness and flavor as those boiled or fried at Abomey-Calavi embankment. On the other hand, the juiciness and the global acceptance mark of the two fish species were significantly higher at the Kpota market than at the Abomey-Calavi embankment (Table 8).

Table 8. Effect of locality, species and cooking mode on fish sensory characteristics.

Variation factors		Tenderness		Juiciness		Flavor		Acceptance	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Localities	Embankment	2.87a	0.16	2.60a	0.13	2.87a	0.14	5.57a	0.20
	Market	3.32a	0.16	3.17b	0.13	3.05a	0.14	6.45b	0.20
Species	*S. melanotheron*	3.15a	0.16	3.05a	0.13	3.05a	0.14	6.125a	0.20
	C. guineensis	3.05a	0.16	2.87a	0.13	2.87a	0.14	5.90a	0.20
Modes	Boiling	3.17a	0.16	2.90a	0.13	2.82a	0.14	5.97a	0.20
	Frying	3.02a	0.16	2.87a	0.13	3.10a	0.14	6.05a	0.20

SE: Standard error; the intra-class means of the same column followed by the different letters differ significantly at the threshold of 5%.

In *S. melanotheron*, the cooking method did not influence the sensory characteristics (Table 9). The same result was also obtained in *C. guineensis* (Table 9). In general, tenderness ranged from 2.75 to 3.35, juiciness from 2.6 to 3.17, flavor from 2.6 to 3.10 over 5 and the global acceptance mark ranged from 5.57 to 6.45 over 10 (Table 9).

Table 9. Effect of interaction between fish species and cooking mode on sensory characteristics.

Species	Mode	Tenderness		Juiciness		Flavor		Acceptance	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
S.melanotheron	Boiling	3.00a	0.22	3.10a	0.19	3a	0.20	6.10a	0.29
	Frying	3.30a	0.22	3.00a	0.19	3.1a	0.20	6.15a	0.29
C. guineensis	Boiling	3.35a	0.22	2.70a	0.19	2.6a	0.20	5.85a	0.29
	Frying	2.75a	0.22	2.75a	0.19	3.1a	0.20	5.95a	0.29

ES: Standard error; the means of the same column followed by the different letters differ significantly at the 5% threshold.

Correlations between the sensory characteristics of Sarotherodon melanotheron and Coptodon guineensis

In *C. guineensis*, the consumer acceptance mark was strongly related to the juiciness (P<0.001, r = 0.665) and secondly to the tenderness (P<0.05, r = 0.360) and flavor (P <0).05, r = 0.358). The juiciness was strongly correlated with the tenderness, while no significant relationship was found between flavor and tenderness and juiciness, respectively (Table 10).

Table 10. Correlations between the sensory characteristics of *C. guineensis* (above the diagonal) and *S. melanotheron* (below the diagonal).

Variations	L*	a*	b*	All	Fmax
L*	1	-0.606***	0.202 NS	-0.460 NS	0.367 NS
a*	-0.60***	1	0.067 NS	-0.048 NS	-0.207 NS
b*	0.63***	-0.154 NS	1	0.658 NS	0.058 NS
All	0.212 NS	0.201 NS	-0.015 NS	1	-0.172 NS
Fmax	0.283 NS	0.325 NS	0.537 NS	0.050 NS	1

L*: lightness; a*: red index; b*: yellow index; F: Shear force; leng: lengthening; NS: P>0.05; *: P<0.05; ***: P<0.001.

As for *S. melanotheron*, the consumer acceptance mark was weakly related to the tenderness (P<0.05, r = 0.352), moderately related to the juiciness (P<0.01, r = 0.434) and strongly related tothe flavor (Table 11). Like in *C. guineensis*, the flavor was not related to the tenderness and juiciness, while a low correlation between juiciness and tenderness was observed (P<0.05, r = 0.297). In *C. guineensis*, the red index was negatively correlated with the lightness (Table 10). Contrary to the yellow index, the red index was negatively correlated with the lightness (P<0.001, r = -0.600) in *S. melanotheron* (Table 11).

Table 11. Correlations between the sensory characteristics of *S. melanotheron* (above the diagonal) and *C. guineensis* (below the diagonal).

Variables	Tenderness	Juiciness	Flavor	Acceptance
Tenderness	1	0.297NS	0.184NS	0.352*
Juiciness	0.525***	1	0.217NS	0.434**
Flavor	0.159NS	0.153NS	1	0.565***
Acceptance	0.360*	0.665***	0.358*	1

NS: P>0.05; *: P<0.05; **: P<0.01; ***: P<0.001.

Discussion

Technological qualities of fish

Coptodon guineensis had a higher fillet yield than *Sarotherodon melanotheron*. The same results were found by Adejonwo *et al.* (2010) in a study carried out in Nigeria, where the fillet yield of *C. guineensis* was 56.3% against53.64% in *S. melanotheron*. This difference in fillet yield between the two species is due to the effect of fish species, sex and catching season.

The difference related to the species is due to the morphometric parameters variability of the two fish species. The relationship between fish morphology and fillet yield was discussed by Lefèvre and Bugeon (2015) and demonstrated in *Cyprinus carpio* (Pereira *et al.* 1999), trout and salmon (Bugeon *et al.* 2006, 2007, 2008, 2010) and in *Hypselobarbus pulchellus* (Raghunath *et al.*, 2016). Several morphological variables related to fillet yield, such as abdominal wall thickness, anal fin thickness and height and the low ventral surface development were used by Bugeon *et al.* (2010) in the rainbow trout to explain variations in fillet yields within the same species. These authors concluded that the fish with the best fillet yields were stockier, thicker and have shorter head lengths. External morphology and internal organs measurements could explain different species fillet yield. In this study, these measures were not taken. A study of the relationship between morphology and fillet yield of these species could confirm the given explanations.

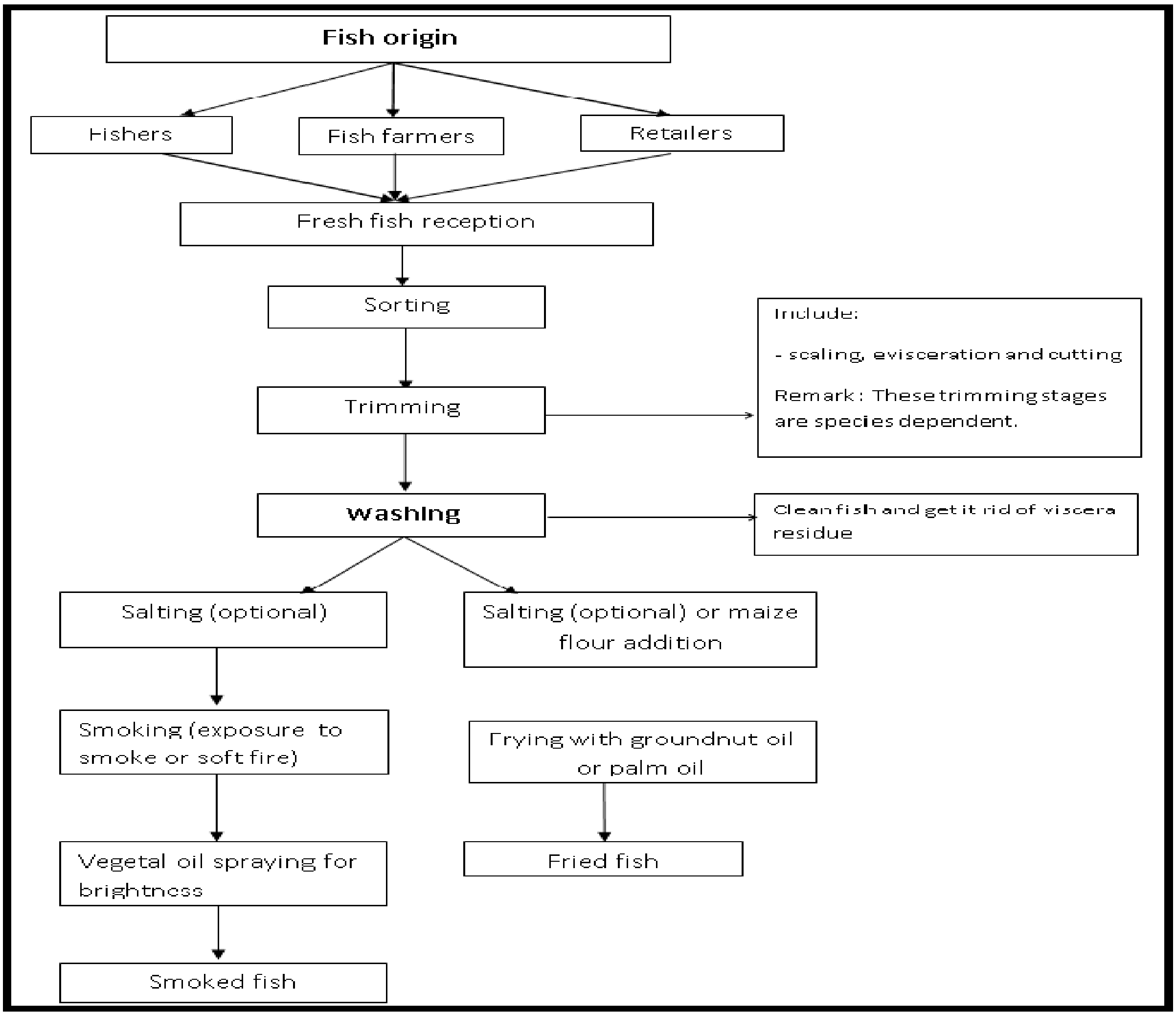

Fig. 1. Diagram of freshwater fish processing in Abomey-Calavi Township.

In addition, the work of Toubiana (2016) on the genetic parameters predictor of cut yield in the bar revealed that the fish with a good fillets yield have a less thick head. This yield is strongly correlated with evisceration-beheading yield and head yield. These observations are consistent with the high fillet yield of *C. guineensis* because *S. melanotheron* has a big head due to the buccal incubation and parental protection of larvae (Lévèque and Paugy 2006, Arizi *et al.*, 2014) contrary to *C. guineensis*. The study by Adejonwo *et al.* (2010) on the flesh composition and the morphological parameters of *C. guineensis* and *S. melanotheron* in Nigeria are in agreement with the previous observations, the head of *C. guineensis* (26.77%) was smaller than the *S. melanotheron* (33.85%).

The sex effect is explained by the difference in gonad weight (reproductive season) (Fauconneau and Laroche, 1995; Mello and Rose, 2005), since evisceration yields are directly related to the liver and gonads weight and to the amount of perivisceral fat. This sex effect was also reported in bar (Peruzzi *et al.*, 2004), in salmon (Neira *et al.*, 2004; Bugeon *et al.*, 2008) and in rainbow trout and brown trout (Bugeon *et al.*, 2008).

In our study, male and female filleting yields were similar. This similarity is due to the fact that fish especially females were not in the reproductive season. Ducarme and Micha (2003) recommended in their study that the *C. gariepinus* fish needs to be filleted before the ovarian mass appearance, 6 to 8 months in intensive breeding, otherwise the fillet yield decreases.

C. guineensis had a pH (6h, 24h and 48h) higher than *S. melanotheron*. The pH is an indicator of the fish freshness. Living muscle pH is close to the neutral but decreases due to lactic acid formation in anaerobiosis and then stabilizes or increases with accumulation of alkaline compounds (Bouazzaoui, 2011; Susanto *et al*., 2011; Dromer *et al*., 2015).

However, the pH (6h, 24h and 48h) values obtained in this study increased from 6.26 to 6.36 in *S. melanotheron* and from 6.53 to 6.60 in *C. guineensis*. These pH values are within the initial pH range (6-7) observed in fish after death (He and Xiao, 2016).

The increase in pH values in this study is due to the formation of alkaline nitrogen compounds (Dromer *et al*., 2015), ammonia and trim ethylamine produced by the spoilage bacteria activity (Hernandez, 2009; Özyurt *et al*., 2009 ; Farid *et al*., 2014 ; Sharifian *et al*., 2014). Indeed, the pH values higher than 6 obtained at 48h mean that the glycogen reserves have been exhausted. These higher pH values promote the development of several types of spoilage micro-organisms and are often responsible for taste and odor alteration. Farid *et al.* (2014) explain that any increase in pH (toward alkalinity) indicates a loss of fish freshness. In our study, the drop in pH was not observed. According to Akter *et al.* (2014), fish pH immediately after death is close to 7. If pH at 6 hours is around 6 and increases at 24 and 48 hours, this implies that fish are caught a little longer before sampling and have begun the autolysis or bacterial degradation process. P*ost mortem* pH changes results similar to those of the current study were obtained by Makawa *et al.* (2014) in *Oreochromis niloticus* stored at room temperature (27-30 ° C). In their study, the evolution was observed from 6 hours *post mortem* and the pH rises to reach 5.98 after 12 hours of storage, but before, a pH drop from 5.94 to 5.92 was observed. The study of Makawa *et al.* (2014) confirms our explanation according to which, fish were caught a while before sampling. On the contrary, in a study carried out by Susanto *et al.* (2011), the pH rising times varied in fish stored at 29°C during 36 hours, in *Thunnus albacares, Epinephelus striatus* and *Cyprinus carpio* at 8h, and in *Osphronemus gourami* at 16h (Susanto *et al*., 2011). These times are beyond, the time (6h) observed in the current study. Thus, the pH evolution is function of the couple time and temperature where, the temperature plays an important role. In addition, pH is function of the glycogen stock level in the *ante-mortem* fish flesh. This glycogen stock is converted into lactic acid which causes the *post mortem* pH drop. The degradation rate of this glycogen varies from one species to the other, or even within the same species (Shackelford *et al*., 1994). This explains the variations in pH evolution according to the time in the various studies. This rate of degradation would be faster in the current study.

Besides, the species effect on pH obtained in this study has already been mentioned by several authors (Howgate, 2009 ; Ozogul, 2010 ; Li *et al*., 2011 ; Veeck 2013 ;Wongwichian *et al*., 2013 ; Kakele *et al*., 2017). The difference in pH between the two species (*S. melanotheron* and *C. guineensis*) could be due to different stress produced from one species to the other that is caused by: the catching conditions, fish high density, fish handling and different catching times. Terlouw *et al.* (2015) have already discussed the variation in pH (drop) depending on the species due to stress. However, according to Köse *et al.* (2001), fish may have an alkaline flesh immediately after capture and therefore, the pH alone can't be used as the freshness indicator of fish. On the other hand, the acceptable limit pH in fish after death varies between 6.8 and 7 (Köse *et al*., 2001; Zang and Deng, 2012) and beyond 7, the fish is considered spoiled (Erkan *et al*., 2011). The pH values in this study do not exceed the limit and are acceptable.

Sensory qualities of fish

The yellow index, lightness and chroma were higher in *S.melanotheron* than in *C. guineensis*. In this study, carotenoid pigments could be at the origin of fillet color. These pigments nature is related to the fish feeding, for example phytoplankton and seaweed rich in carotenoids that feed fish in the "acadja" breeding environments of Nokoué Lake. These pigments, the lutein and zeaxanthin are responsible for the yellow coloring and the astaxanthin for the red pigmentation of fish flesh (Choubert, 1992).

The lutein and zeaxantine are found in abundance in micro-seaweed and green plants (Zheng *et al.*, 2015) while astaxanthin is found in invertebrates (Choubert, 1992). If *S. melanotheron* has a yellow index higher than *C. guineensis*, the possible explanation is that *S. melanotheron* consume more micro seaweed and better absorb lutein and zeaxanthin than *C. guineensis*. This is confirmed by the fact that *C.guineensis* flesh is redder (invertebrates consumption) than that of *S. melanotheron*, but not statistically significant. According to Choubert (1992) the color variation is related to the pigments digestibility, their absorptions and their fixations in the fish muscle which can vary from one fish species to the other.

The lightness is higher in *S. melanotheron* than in *C. guineensis*. This lightnessis related to the type of muscle that dominates in the fish. Listrat *et al.* (2016) state that fish muscle is consisted of predominantly translucent white muscle, superficial red muscle rich in myoglobin and pink muscle. The flesh of *S. melanotheron* and *C. guineensis* could be composed of white muscle rather than red but *S. melanotheron* has whiter muscle fiber than *C. guineensis*. This may explain the higher lightness in *S. melanotheron* than in *C. guineensis*. If Lebret and Picard (2015) state that the fish fillets color is related to its composition as well as to the muscular tissue structure, then, a study of the muscular structure of the two species can confirm or invalidate the given explanations. Among other things, the red muscle is rich in myoglobin, a blood pigment.

After evisceration and filleting, the residual blood in the red muscle of *S. melanotheron* flesh could be more absent or less important than the one in *C. guineensis* flesh. This may result in lighter flesh in *S. melanotheron* than in *C. guineensis*. According to Dromer *et al.* (2015), a dark flesh contains residual blood and has undergone myoglobin oxidation (muscle pigment) which browns flesh and darkens it. The oxidation of this residual blood and its amount in the muscle can vary from one species to the other and from one individual to the other and consequently influence the flesh lightness of *C. guineensis*.

Furthermore, according to Lebret and Picard (2015), the fish fillets color can also be influenced by the *post mortem* pH, so a flesh whose final pH is low has a light color. This is consistent with the pH results of this study, where *S. melanotheron* with a low pH (pH 48 = 6.36) has a lighter flesh than *C. guineensis* (pH48 is 6.60). Indeed, the bacterial activity is more advanced at higher pH with fish flesh proteins degradation. This proteins degradation due to the bacterial activity induces changes in fish flesh color and texture. This explanation demonstrates why *C. guineensis* have a higher pH and a darker flesh than *S. melanotheron*.

The lightness has varied according to the sex and *C. guineensis* males'fillets were lighter than those of females. The muscle structure may explain these differences in fillet color (Choubert *et al.*, 1997; De Francesco *et al.*, 2004; Mairesse *et al.*, 2005; Listrat *et al.*, 2016). With equal pigment content, a high fiber density expresses color by modifying the reflective properties of the flesh (Johnston *et al.*, 2000). Moreover, Lefèvre and Bourgeon (2008) explain that during fish sexual maturation, muscle pigments are stored and are more concentrated in the ovaries in the female and the skin in the male which causes significant muscle discoloration. In this study, the lightness dominates other colors. In this case, it is the white muscle that is translucent in fish and is the majority than the red and pink muscle that has the ability to reflect light. If *C. guineensis* males fillets are lighter than *C. guineensis* females, this implies that *C.*

guineensis males have a higher muscle fiber proportion and white muscle than of *C. guineensis* females.

Besides, the color varied significantly depending on the treatments (whole, pre-processing, frying and smoking). The flesh of the smoked and fried fillets was lighter than that of the raw fillets and a loss in the red index was observed. On the other hand, the yellow index of raw fillets increased during frying and smoking. The same treatment effects on color were found in fried, boiled and braised *Engraulis encrasicholus* in Turkey (Uran and Gokoglu 2014) and in smoked catfish (*Micrones nemurus* and *Cryptotherus micronema*) in Indonesia (Huda *et al.*, 2010).

According to ANSES (2010) and Choubert (2010) smoking and frying lead to a change in product color and induce surface or depth heterogeneity. If smoked and fried fish fillets are lighter and less red than raw fillets, this may be due to the loss in pigments (carotenoids) during cooking, which was confirmed by Masuda *et al.* (1996) in chum salmon (*Oncorhynchus keta*). Lefèvre *et al.* (2016) agreed with this in a study carried out on trout where raw fillets of lean line trout were less light than those offat line trout, but this difference in lightness disappears after cooking or smoking.

The increase in the yellow index from raw fillets to fried and smoked fillets may be due to the cooking temperature, the interactions that occur between smoke constituents and proteins, the fats and the chosen wood nature (Knockaert, 1990) during smoking.

The proteins denaturation during hot smoking (50%) evoked by ANSES (2010) can also be at the origin of this yellow index variation. On the contrary, the color varied according to the species. The lightness of fried and smoked *S. melanotheron* was higher than that of *C. guineensis*. This effect has been reported by Choubert (2010) who states that color variations during heat treatment are species dependent. As for the raw flesh texture, it was not different according to species, sex and treatments (whole and pre-processed). Nevertheless, the shear force (Fmax) recorded by treatment and species in *C. guineensis* was higher than that in *S. melanotheron*. Similar results have been reported at the species level by Jain *et al.* (2007) in Indian carp (*Labeo rohita*) where, the mechanical resistance varied between 48.714N and 95.778N. By opposite, Fauconneau (2004) obtained mechanical resistance of raw flesh of carp (13-15N), catfish (8.8N) and brown trout (8.4N) lower than those in the both studies. Leduc (2011) explained that the fish skins have very different textures.

The whiting (*Merlangius merlangus*) and the cod (*Gadus morhua*) have a very fragile integument that is quickly damaged compared to different flatfish such as the plaice which has a very robust dermis and epidermis.

This observation explains the resistance of the flesh of *C. guineensis* which was higher than that of *S. melanotheron*. However, the juiciness and the global acceptance mark of the two fish species by the consumer were significantly higher at the Kpota market than at the Abomey-Calavi embankment. Although the results were similar (P>0.05), *S. melanotheron* was more juicy than fried or boiled *C. guineensis*.

Concerning the locality effect, the cadaveric rigidity state of fish from the different localities can explain the difference in juiciness. According to FAO (1999) the processor appreciates the little older fish that have passed *rigor mortis*. This agrees with the obtained results because the fish collected at the market were older. They were bought by the retailers at the embankment from fishers and could spend a long time before being sampled for sensory testing. Besides, considering the water content of *S. melanotheron* compared to that of *C. guineensis*, logically *C. guineensis* should be softer, firmer and juicier than *S. melanotheron*; this is not the case with the sensory evaluation by the jury. The result shows the subjectivity of this evaluation. A nutritional analysis (lipid content) is needed to support these arguments.

Conclusion

The study shows that *C. guineensis* has a good fillet yield than *S. melanotheron*. But the high pH values of *C. guineensis* flesh predispose them to rapid deterioration than *S. melanotheron*. *S. melanotheron* is of technological interest compared to *C.guineensis* in terms of color. It expresses better the yellow index, the lightness and the chroma. On the contrary, *C. guineensis* with its higher water content than that of *S. melanotheron* has a commercial interest for its juiciness and tenderness. The processing process such as smoking gives more lightness than frying in fish. Frying, on the other hand, improves the yellow index, red index and chroma more than smoking. Following the sensory tests, the fried or boiled fish have the same organoleptic characteristics. The application and the optimization of the quality parameters that have given the best results will guarantee a better technological and organoleptic quality of fish to the consumers. Finally, the use of conservation good practice after fishing and fish processing could improve fish qualities.

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