Energy and Earth Science
Vol. 6, No. 1, 2023
www.scholink.org/ojs/index.php/ees
ISSN 2578-1359 (Print) ISSN 2578-1367 (Online)

Original Paper

Comparing Smoked Fish Quality of Traditional and Improved Modern Ovens Using Dendro-Energy from Mangrove and Tropical Forest Woods and Implications for Conservation in Central African Atlantic Coast, Cameroon

Gordon N. Ajonina[1,2*], Coleen Mumbang[2,3], Jacqueline Therese Ngo Oum[1], Fani Momo Dogmo[1], Minette Tomedi Eyango[1] & Francois Tchoumbougnang[1]

[1] Institute of Fisheries and Aquatic Sciences, University of Douala (Yabassi), P.O. Box 7236 Douala, Cameroon

[2] Cameroon Wildlife Conservation Society, CWCS Coastal Forests, Mangrove & Marine Programme, BP 54 Mouanko, Littoral Region, Cameroon

[3] Faculty of Sciences, Department of Plant Sciences, University of Buea, P.O. Box 63 Buea, Cameroon

Received: December 1, 2022 Accepted: December 13, 2022 Online Published: February 11, 2023
doi:10.22158/ees.v6n1p1 URL: http://dx.doi.org/10.22158/ees.v6n1p1

Abstract

Smoked fish qualitative organoleptic parameters (color, smell, texture and taste) and quantitative proximate parameters (protein and ash content and salt mineral: Ca, Iron, Mg, Zn content in ash) of two species (Ethmalosa fimbriata and Pseudotolithus elongatus) smoked in traditional and modern ovens with wood from mangrove (Rhizophora racemosa) and two tropical forest (Sacoglottis gabonensis and Albizia glaberrina) species in Douala-Edea Atlantic coast, Cameroon are presented. Women processors significantly spend more time, consume more wood and consequently release significant amount of carbon dioxide (CO_2) to the environment with traditional smoking system. Organoleptic characteristics were significantly different with ovens types but not with different wood species except color (black and marron from inland forest wood species and preferred brownish and golden brown colored smoked fish from mangrove wood). Fish food constituents yielded for improved smoked oven: Protein content (65.52%; 69.45%), ash content (6.21%; 5.57%) and traditional oven: Protein content (70.65%; 75.00%), ash content (5.73%; 6.33%) for Ethmalosa fimbriata and Pseudotolithus elongatus respectively. Results also confirmed good dietary quality of fish samples *(source of calcium, iron and magnesium). Some energy efficient management techniques and conservation implications were proposed regarding qualitative and quantitative improvement of smoked fish.*

Keywords

Dendro-energy, smoked fish, smoke ovens, mangrove and inland tropical forest woods, conservation, Cameroon

1. Introduction

In Cameroon, fish accounts for 49% of the diet as a source of protein of animal origin in households. Its importance is even greater among the poorest segments of the population (MINAGRI, 2002). Imports of this foodstuff have been estimated at more than 80,000 tons per year in an attempt to supplement fisheries production of 120,000 tons in 2002 (FAO, 2004). On the basis of per capita consumption estimated at 16kg before the devaluation in 1992, current annual demand would exceed 280,000 tons. In addition, fish remains a highly perishable commodity after capture, hence the need to improve preservation techniques, particularly smoking. This method of conservation probably dates back to prehistoric times and is one of the oldest known methods of preserving fish products after drying and salting (Knockaert, 1990).

Today, smoking is the only widely used means of preserving fishery resources in the Douala-Edea Central African coastal Atlantic area. According to the results of work carried out by the Cameroon Wildlife Conservation Society (CWCS), a national non-governmental organization working since 1997 in the area conducting studies and community based conservation activities to develop a participative management plan, in 2009, this fish smoking activity occupies entirely the women of the area. These women make extensive use of traditional smokehouses (Figure 1, Table 1), smoking more than 1,000 tons of fish per year and sell them mainly to the large cities of Douala, Yaoundé and western Cameroon through intermediaries' women called "bayam-sellam". Furthermore, traditional smokehouses have serious health and environmental concerns in the area (Ajonina et al., 2005). They are responsible for diseases such as cancer, headaches, eye ailments and the annual clearing of more than 140 ha of mangrove forest, hence the need for efficient wood bio-energy use management through the improved smokehouses set up by CWCS in early 2000s in the Douala-Edea area (Ajonina & Eyabi, 2002; Feka et al., 2009). Since the establishment of this innovative improved smokehouse initiative with partners (Forkam et al., 2020), some sensitization and training campaigns have been conducted to enhance the use and adoption of the new technology approved by the Cameroonian government that featured as one of the projects under validation in the Clean Development Mechanism (CDM) (CDM-ONFI-CWCS, 2009**)**.

Traditional ovens

Chorkor smoke oven Hybrid smoke oven

Figure 1. Types of Smoke Ovens Commonly Used

Table 1. Comparison of Some Commonly Used Fish Smoking Ovens

Oven type	Construction materials	Performances					References
		Fish smoking time (hours)	Wood consumption (m^3)	Control of operations	construction cost (US $)	Product quality	
Traditional	Planks, nails, meshes	3-4	1.4	Difficult	15 000	Brilliant	(Feka *et al.*, 2009) Marion (2009) Eyabi (1994)
Improved oven with local material	Planks, nails, sand, meshes, corrugated iron sheets	5-8	0.9	Easy	32 500	Good	(Feka *et al.*, 2009) Marion (2009) Eyabi (1994)
Hybrid oven (chockor)	Sun dry bricks, sand, nails , meshes	10-18	1.0	Easy	17 500	Good	Eyabi (1994) Eyabi (2010)

This study was motivated with main objective to better appreciate the extent of this innovation from existing tradition ovens and the preference to certain species of wood used in both oven types especially mangrove wood with respect to other inland tropical woods with not yet scientific evidence and their implications on the quality of the final product, smoked fish.

2. Materials and Methods

Site description

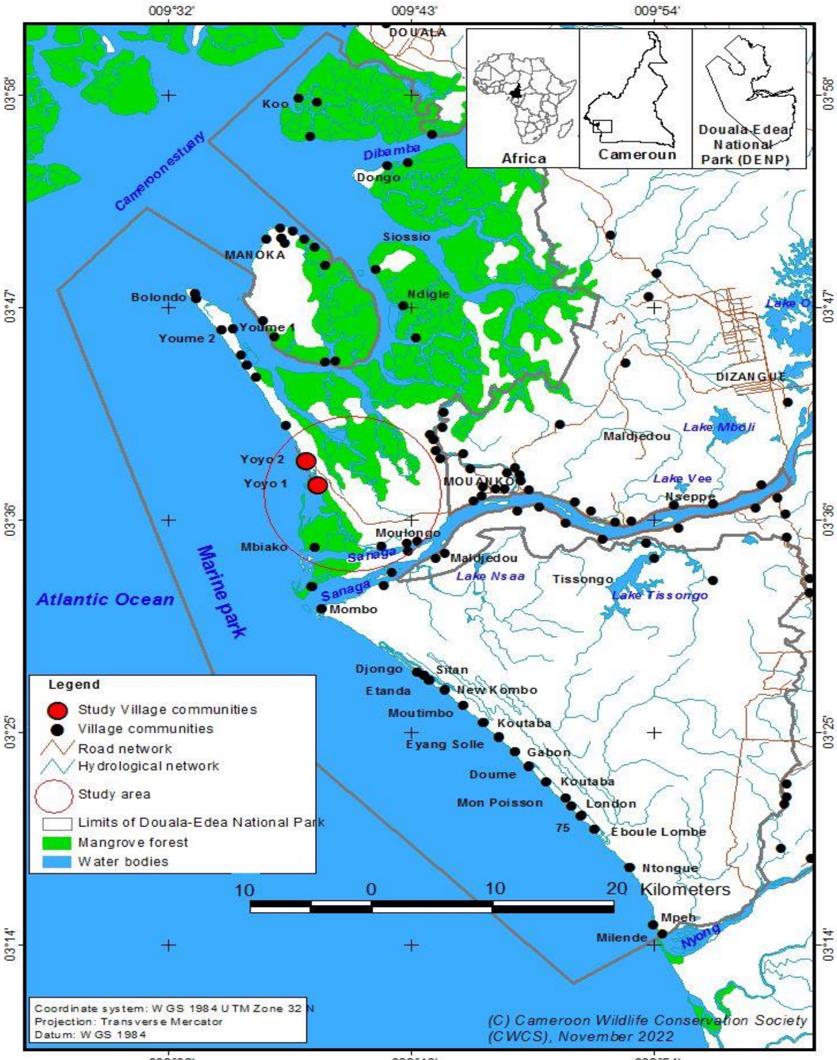


Figure 2. Map Showing the Study Village Communities

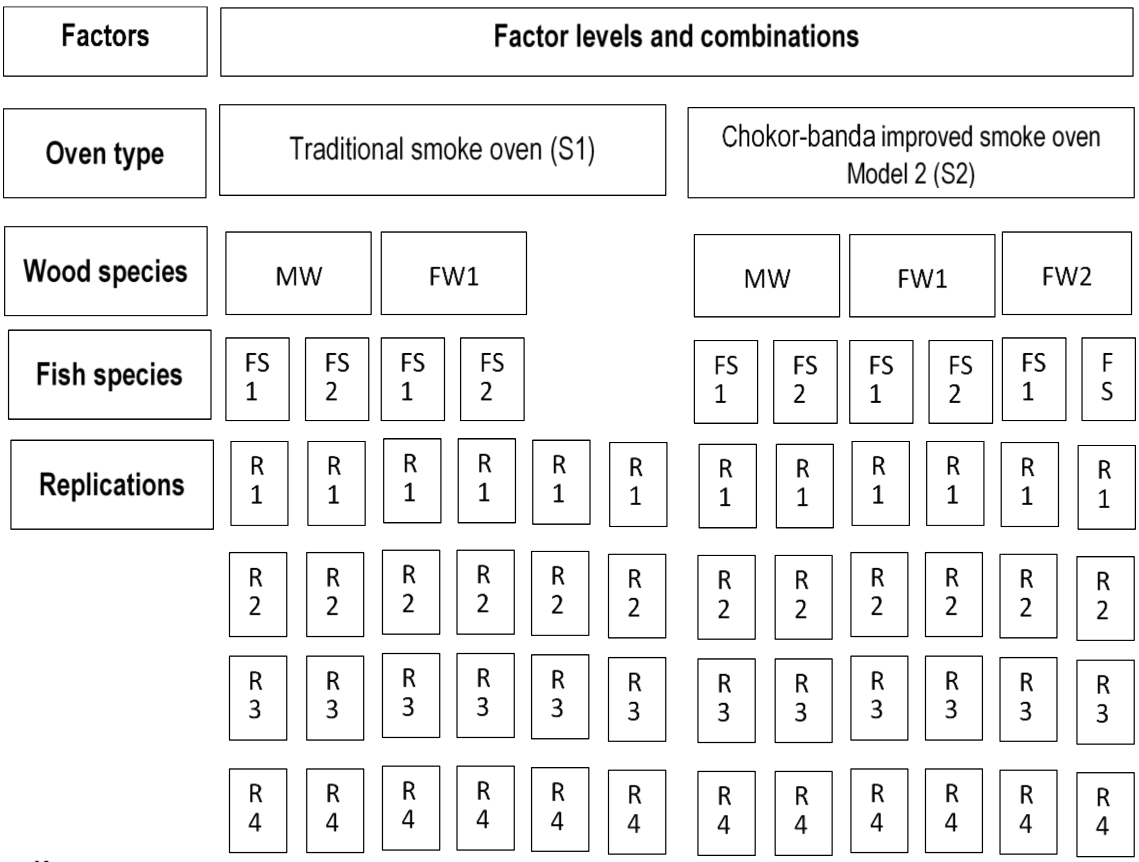
The study coastal village communities (Yoyo 1 & Yoyo 2) are within the buffer zone of the newly regazetted Douala-Edea National Park (DENP) in 2018 from old wildlife reserve, situated some 75 km south west of Douala city, Cameroon's economic capital. In the Districts of Mouanko and Manoka in the Littoral Region within the Douala-Kribi basin of the coastal Atlantic Ocean (Latitude 3° 14' 3°50'N and longitude (9°34'-10°03' E). Covers an area of about 300,000 ha with more than 50% terrestrial and less than 50% marine area stretching for over 100 km along the Cameroon coastline (Figure 2). The region has an equatorial climate type, characterized by abundant rains (3,000-4,000 mm) and high temperatures with a monthly average range of (24-29) ^{o}C. These conditions have favored the development of many diverse habitats spanning terrestrial, marine, river and lake ecosystems with diverse sites of both terrestrial and aquatic species. Wildlife populations and other natural resources of newly created national park are continuously threatened by hunting, bush meat trade and habitat destruction as result of increase human population in the area including oil-gas exploration and exploitation activities in some sections (though this has stopped with creation of national park in 2018). The humid forests and mangrove vegetation is of high biological value that serves as a refuge for many resident and seasonal migratory birds of over 80 species (Ajonina et al., 2020). The coastal forest is also made up of 40 000 ha of giant mangrove forest (about 20% of the total mangrove stands in Cameroon) with max diameter 120 cm and max height of 60m of seven plant species, with the dominant species *Rhizophora racemosa* and *Avicennia germinans* clearly displaying a spatial zonation pattern (Ajonina, 2008; Ajonina et al., 2014; Ajonina, 2022). In addition, the park also hosts a varying number of vegetation types, amongst which are freshwater swamps and degraded primary forest. The park was regazetted due to threat and encroachments and over-exploitation coupled with the lack and/or poor enforcement of policies since its creation initially as a wildlife reserve in 1932 essentially terrestrial to put exploited areas and over 40 communities as buffer zones and marine extension compensation zone of over 140 000 ha. This vast marine park, the first of its kind in Cameroon is the fifth largest in western Africa. The park is also important for the reproduction of several cetaceans, manatees, and marine turtles (Fretey, 2021). The major economic activity is fishing, and about 500 tons of fish are harvested annually by the two fishing localities in which this study was conducted (CWCS, 2001).

Mobilizing participants and experimental materials

To better own the results of this study, participatory process approach (Forkom et al., 2020) was adopted by CWCS to conduct this experimentation through organizing three major formal meetings. The first meeting was a planning meeting with the relevant technical departments where the experimental design (Figure 3) was explained to participants. The second meetings then mobilized all stakeholders involved in smoking in the study fishing communities with assignment of different tasks to the technical services concerned: the conservation service for wood supply responsibility for the provision of the inland tropical species (*Sacoglottis gabonensis* “Bidou” and *Albizia glaberrina* “Essate”); supply of fish by the department of fisheries making contacts with fishermen to provide the two species of fish *Ethmalosa fimbriata* “bonga” and *Pseudotolithus elongates* “bosu”). To sensitize the population on the environmental and socio-economic benefits of outcome of the experiment, the third meeting was organized chaired by the district head bringing together all parties concerned including the technical services, traditional leaders and the population especially the participants of the villages selected for the experiment. Having sensitized the stakeholders, a measure~~d~~ of wood and fish species was then distributed to 24 fishing smoking ovens having both traditional and modern ovens with each woman assisted by an observer who recorded the information (quantity of wood used, smoking time, etc. ...) as the process went on.

Experimental structure

The experimental structure was consolidated as a 2×3×2 factorial arrangement with 2 types of smokehouses (traditional oven, modern oven), 3 types of wood species (mangrove: *Rhizophora* spp "Matanda" and inland rainforest species: *Sacoglottis gabonensis* "Bidou" and *Albizia glaberrina* "Essack") and 2 types of fish species (*Ethmalosa fimbriata* "bonga" and *Pseudotolithus elongates* "bosu" and four replications per treatment (Figure 3) though fourth replication with the second fish species, *Pseudotholithus elongates* could not be possible because of the rarity of the species.



Key:

Smoke oven types (2) (S1, S2); Wood species types (2) (MW: Mangrove wood, FW: Inland tropical forest wood); FS: Fish species; R: Replications (4) (R1 – R4)

Figure 3. 2x3x2 Experimental Model to Compare Effects of Wood Sources and Fish Smoking Oven Types on Some Smoked Fish Parameters

Data collection

In collaboration with CWCS staff and technical services, smokers were monitored throughout the smoking operation by recording on pre-established data collection forms. After smoking, a few fish were randomly selected from each batch, wrapped in aluminum foil, coded and taken to the laboratory for the determination of chemical compounds (water content, protein, ash, mineral salts).

Determination of wood and smoked fish quality parameters

Quantitative field assessment include used wood volume, biomass and carbon emissions rate per sterre ($1m^3$) of wood through standard forest inventory and mensuration techniques (Husch et al., 2003; Ajonina, 2008) using the formulae:

$$\text{Volume/sterre, } V = Va/Vc = \sum \tfrac{1}{2}L\,(At+Ab)/L \times l \times H \tag{1}$$

$$M = \rho \times V \tag{2}$$

$$M_C = \tfrac{1}{2}\,M \tag{3}$$

$$M_{CO2} = M_C \times 3{,}67 \tag{4}$$

And the determination of Energy Efficiency (EF) of each type of oven using the method explained by Feka (2009):

$$EF = (MC_{\text{fish weight fraction}} \times W_{\text{fish fresh weight}} \times E_{\text{fish}})/W_{\text{wood}} \times Cal_{\text{wood}} \tag{5}$$

Where in all cases: Va = actual wood volume in m^3; Vc = cubic volume of stark of wood including air spaces in m^3; L = wood sterre length in cm; I = wood sterre width in cm; H = wood height in cm; A(t, b) = Surface area at the ends (top and bottom) of a log of wood in as sterre, ∑= sum of the logs of wood in the sterre, M = wood sterre biomass in kg; ρ = wood density: *Rhizophora* = 0,89 (Fearmside, 1997), 0,66 (Djomo et al., 2011) in land forest woods; M_C = carbon mass in carbon in kg; M = wood biomass; M_C = carbon mass in kg; M_{CO2} = quantity of carbon dioxide emission; EF energy efficiency; $MC_{\text{fish weight fraction}}$ = Loss in weight of fish due to smoking in kg; $W_{\text{fish fresh weight}}$ = fish fresh weight in kg; E_{fish} = Energy necessary to raise water in fish (5800kJ/kg); and W_{wood} = wood weight in kg; Cal_{wood} = wood calorific value *R racemosa* = 16,9MJ/kg, in land tropical forest wood = 4770 cal/g (Doat 1977).

Laboratory determination of proximate chemical (composition) quantitative smoked quality parameters

This included protein and ash content and salt mineral (Ca, Iron, Mg, Zn) content in ash using standard methods (AOAC, 1980; AFNOR, 1981). Organoleptic parameters of ordinal-scale scored qualitative quality appreciation assessments of smoked fish by fish smoking women include ordor (typical smoked fish ordor), color (black, marron, golden brown, brownish), taste (bad, good, very good) and texture (humid, hard).

Statistical data analysis

Both descriptive (tables, graphs, etc.) and inferential statistical analysis (hypothesis tests) especially Analysis of variance (ANOVA) procedure including sign tests were used to analyze the qualitative and quantitative data (Quinn & Keough, 2002).

3. Results

Socioeconomic characteristics of participants

Of all the women that participated most (more than 50%) were aged 35+; more than 60% from secondary school and with more than 35% having 5-10 years' experience in the activity in the area and were mostly Nigerians (Figure 4).

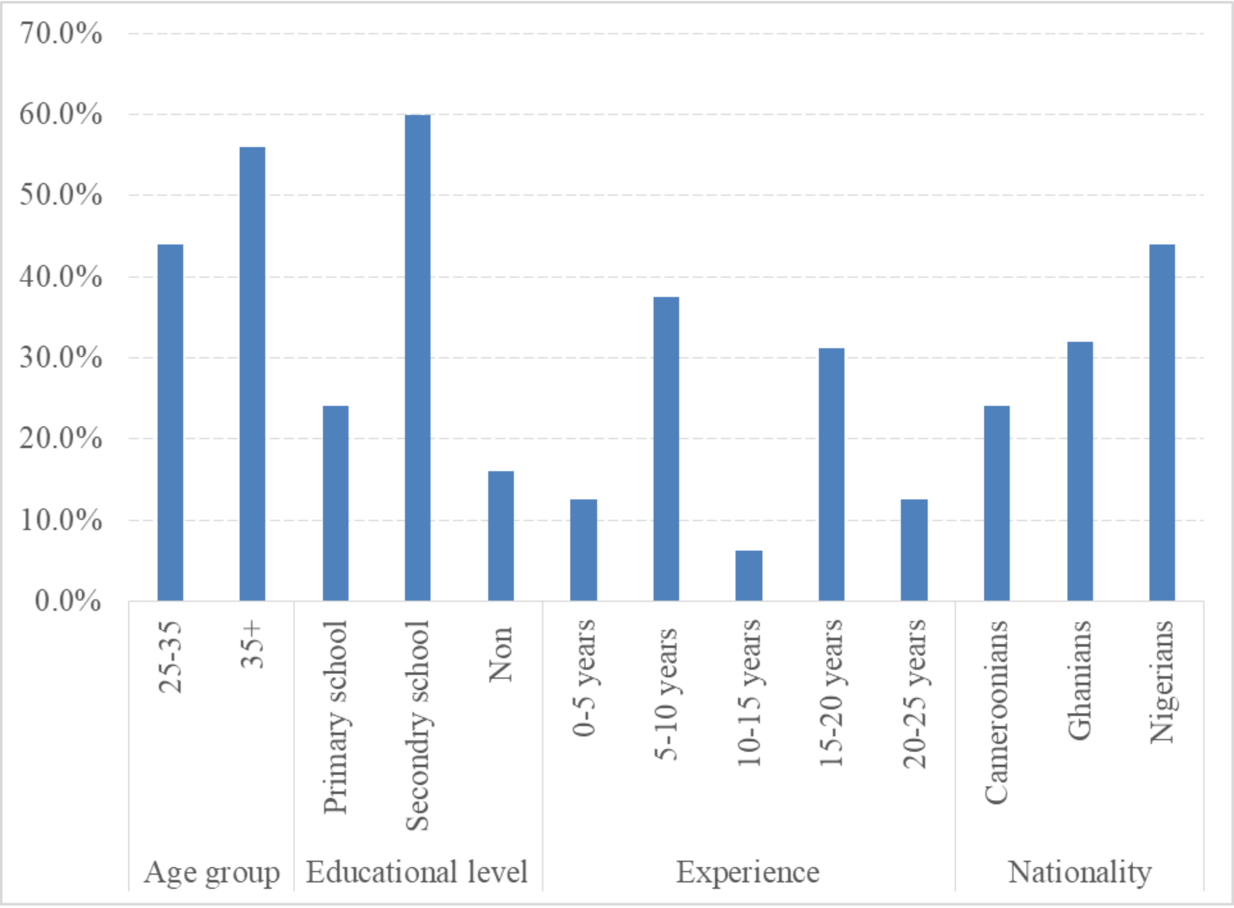


Figure 4. Socioeconomic Characteristics of Fish Smoking Women in the Village Study Communities

Comparing quantitative parameters of wood and smoke oven types

Table 2. Comparison of Characteristics of Types of Ovens and Wood Species Sources

Parameter	Wood species	Oven type	Mean	SD	CV (%)	df	F
Volume used (m^3)	*Albizia glaberrina*	Traditional oven	0.15	0.11	75.38	2	0.9ns
		Improved oven	0.09	0.02	18.34		
	Sacoglottis gabonensis	Traditional oven	0.14	0.13	89.17		
		Improved oven	0.05	0.04	82.68		
	Mangrove wood	Traditional oven	0.18	0.09	50.96		
		Improved oven	0.16	0.00	0.00		
CO_2 (t/stere)	*Albizia glaberrina*	Traditional oven	0.18	0.14	75.38	2	5.8**
		Improved oven	0.11	0.02	18.34		
	Sacoglottis gabonensis	Traditional oven	0.17	0.15	89.17		
		Improved oven	0.06	0.05	82.68		
	Mangrove wood	Traditional oven	0.25	0.15	57.49		
		Improved oven	0.96	0.95	98.74		
Efficiency	*Albizia glaberrina*	Traditional oven	0.39	0.22	56.50	2	5.6**
		Improved oven	0.46	0.11	23.57		
	Sacoglottis gabonensis	Traditional oven	0.33	0.27	81.53		
		Improved oven	1.27	0.56	44.27		
	Mangrove wood	Traditional oven	0.00	0.00	58.12		
		Improved oven	0.12	0.18	141.09		
Fish smoking time (hours)	*Albizia glaberrina*	Traditional oven	13.99	2.63	18.80	2	3.5*
		Improved oven	14.65	1.09	7.45		
	Sacoglottis gabonensis	Traditional oven	17.49	2.95	20.11		
		Improved oven	14.67	2.38	13.58		
	Mangrove wood	Traditional oven	20.84	4.72	22.66		
		Improved oven	15.42	0.00	0.00		

Note. ** Significant ($P<0.01$), * Significant ($P<0.05$), NS Not significant ($P>0.05$).

Generally, women processors spend more time (17.08±4.65 hours) and consume more wood 0.14±0.1m^3 using the traditional smokehouse. This excessive use of wood promotes the release of more CO_2 into nature. The comparative capacity characteristics of the traditional and improved smokehouses as summarized in Table 2 showed that the volume of wood used with the system of improved smokehouse was less elevated with an average of 0,09±0,02 m^3 for "Essack" 0,05±0,04m3 for "Bidou" and 0,16±0,09 m^3 for mangrove wood; against an average of 0,15±0,11 m^3, 0,14±0,13 m^3 and 0,18 m^3

respectively for the same wood species in the traditional smokehouse. The mass of CO_2 released depended on the amount of wood used and the type of smoker. From this table, it appears that the high CO_2 masses released were from traditional oven explained by the large openings of this type of smokehouse, which causes a high loss of smoke and heat. There was a significant difference between the smoking time in the traditional and improved systems with an average of 15.05±1.09 (hours) with "Essack" and 17.49±2.38 (hours) with "Bidou". On the other hand, the smoking time with mangrove wood in the traditional smokehouse 20.08±4.7 (hours) was higher than that of the improved smokehouse 15.42±0.06 (hours) that burns slowly but steadily. This reduction in time could be due to the ability of mangrove wood to burn even under humid conditions. These differences in high times with the two types of in land tropical forest wood could be explained by the moisture content of the wood, as the lack of aeration in the improved oven prevents air from maintaining the flame important to ensure that the combustion chamber is well ventilated so that the flame is always kept burning.

Qualitative assessments by organoleptic characteristics

In general the organoleptic characteristics of smell, texture and taste of the fish smoked were significantly different with the different types of ovens but not with different species of wood except the color obtained with the two species of forest wood (Essack & Bidou) which were identical (black and marron), but those obtained with the mangrove wood brownish and golden brown. In general, by order of coloration of smoked fish preference, is the brownish and golden brown colors.

There is no significant difference in the color and taste of fish obtained from traditional and modern oven, but there is a very significant difference ($p = < 0.01$) in the texture. This significant difference would be explained by the difficulty to reduce the burning fire contained in the combustion chamber of the traditional oven with the consequence of a hyper dehydration in the product; on the other hand, the improved ovens would maintain a regular pyrolysis during the whole smoking process, leading to a uniform reduction of the water contained in the fish flesh. The different species of wood used in this study have no influence on the final product organoleptic characteristics except coloration appreciation. This could be due to the fact that the two species of in land tropical forest wood would contain almost the same compounds as the mangrove wood.

Proximate chemical composition of smoked fish

Proximate chemical composition of smoked fish using wood and smoked oven types are showed in Table 3.

Table 3. Chemical Composition of Smoked Fish per Type of Oven and Wood Source Used

Parameter	Fish species	Smoke oven	*Wood*	Mean	SD	CV(%)	df	F
Moisture Content (%)	*Ethmalosa fimbriata*	Traditional oven	*Albizia glaberrina*	19.22	12.13	63.1	2	5.48*
			Sacoglottis gabonensis	23.53	7.77	33.0		
			Mangrove wood	17.53	2.71	15.5		
		Improved oven	*Albizia glaberrina*	33.88	12.29	36.3		
			Sacoglottis gabonensis	22.57	4.62	20.5		
			Mangrove wood	28.55	.			
	Pseudotolithus elongatus	Traditional oven	*Sacoglottis gabonensis*	21.68	.			
			Mangrove wood	9.78	.			
		Improved oven	*Sacoglottis gabonensis*	17.95	.			
			Mangrove wood	31.28	.			
Proteine (%)	*Ethmalosa fimbriata*	Traditional oven	*Albizia glaberrina*	71.17	6.84	9.6	2	5.12*
			Sacoglottis gabonensis	70.28	9.25	13.2		
			Mangrove wood	70.52	4.00	5.7		
		Improved oven	*Albizia glaberrina*	62.02	10.25	16.5		
			Sacoglottis gabonensis	66.30	3.60	5.4		
			Mangrove wood	67.71	.			
	Pseudotolithus elongatus	Traditional oven	*Sacoglottis gabonensis*	75.54	.			
			Mangrove wood	74.46	.			
		Improved oven	*Sacoglottis gabonensis*	72.65	.			
			Mangrove wood	66.26	.			
Ash content (%)	*Ethmalosa fimbriata*	Traditional oven	*Albizia glaberrina*	5.61	0.16	2.9	2	0.44ns
			Sacoglottis gabonensis	7.04	1.95	27.7		
			Mangrove wood	6.02	0.36	6.0		
		Improved oven	*Albizia glaberrina*	6.00	1.01	16.8		
			Sacoglottis gabonensis	5.50	0.71	12.8		
			Mangrove wood	5.71	.			
	Pseudotolithus elongatus	Traditional oven	*Sacoglottis gabonensis*	5.55	.			
			Mangrove wood	5.60	.			
		Improved oven	*Sacoglottis gabonensis*	5.37	.			
			Mangrove wood	7.31	.			
Calcium(mg/kg)	*Ethmalosa fimbriata*	Traditional oven	*Albizia glaberrina*	4500	2517	55.9	2	4.56ns
			Sacoglottis gabonensis	1750	1100	62.9		
			Mangrove wood	2100	2206	105.1		

	Improved oven	*Albizia glaberrina*	1175	171	14.5
		Sacoglottis gabonensis	1100	383	34.8
		Mangrove wood	1600	.	
Pseudotolithus elongatus	Traditional oven	*Albizia glaberrina*	900	.	
		Sacoglottis gabonensis	1400	.	
	Improved oven	*Albizia glaberrina*	1100	.	
		Sacoglottis gabonensis	880	.	

Note. ** Significant (P<0.01), * Significant (P<0.05), NS Not significant (P>0.05).

Water content. There is a significant difference between the water content of the fish smoked in the Chorkor ovens, where the averages obtained are between 22.57 and 33.88% for *Ethmalosa fimbriata* and between 17 and 31% for *Pseudotolithus elongatus*, while they are between 17.53% and 23.53% for *Ethmalosa fimbriata* and between 9.77 and 21.68% for Pseudotolithus elongatus in the traditional ovens. This translates into a hyper dehydration of the fish smoked in the traditional ovens leading to more or less friable products, thus making it very difficult to transport them, unlike those smoked in the Chorkor ovens.

Protein content. There was a statistically significant difference between the protein contents. Those obtained in the Chorkor ovens are more reduced (with an average of 65.52% for *Ethmalosa fimbriata* and 69.45% for *Pseudotolithus elongatus*) compared to those obtained with fish smoked in traditional ovens presenting an average of 70.65% for *Ethmalosa fimbriata* and 75.00% for *Pseudotolithus elongatus*. The variations observed, particularly in the traditional smokehouses, can be explained by a concentration of proteins caused by a decrease in the water content of the product, which is more accentuated. During these operations there is an evaporation of water under the effect of heat the variations coming from the slight denaturation that occur during smoking.

Ash content. There was no significant difference between the averages obtained average between 5.6 and 7.04 for *Ethmalosa fimbriata* and between 5.54 and 5.6 for *Pseudotholithus elongatus* with the traditional smokehouses against an average between 5.4 and 5.99 for *Ethmalosa fimbriata* and between 5.31 and 5.36 for *Pseudotholithus elongatus* with the Chorkor smokehouses.

Calcium content. There was statistically significant difference with higher calcium content in the traditional smokehouses (with an average of 2783mg/kg *Ethmalosa fimbriata* and 1150 mg/kg *Pseudotolithus elongatus*) than in the improved smokehouses (with an average of 1291.66mg/kg *Ethmalosa fimbriata* and 990 mg/kg *Pseudotolithus elongatus*). The high amounts of calcium with traditional smokehouses would be explained by a hyper dehydration of the smoked fish, making it difficult to separate the flesh from the bones during its determination in laboratory. Fish bones are an important source of calcium, which is essential for the formation, growth and rigidity of bones, the development of teeth, muscle contraction, nervous irritability, blood coagulation and cardiac activity.

Iron content. There was no statistically significant difference between the amount of iron obtained (average between 0.68 and 8.17 mg/kg for *Ethmalosa fimbriata* and 24.95 and 31.93 mg/kg for *Pseudotolithus elongatus*) for the products from the traditional smokehouses and an average between 0.25 and 2.79 mg/kg for *Ethmalosa fimbriata* and 33.68 and 50.14 mg/kg for *Pseudotolithus elongatus* for the products from the improved smokehouse. These different values observed with the different species could be due to the diet of each species, their concentration in the natural environment. Iron is necessary for the formation of hemoglobin, pigment of red blood cells ensuring the transport of oxygen, in the growth of the fetus and the child. However, we must note that the needs vary according to physical activity and age. Iron needs are higher during growth, in athletes (loss of iron through sweat), in women during pregnancy, lactation and during menstruation.

Magnesium content. There was no statistically significant difference between the amount of magnesium obtained (average between 911.2 and 1826 mg/kg for *Ethmalosa fimbriata* and 668 and 972 mg/kg for *Pseudotolithus elongatus*) for the products from the traditional smokehouses and an average between 729.25 and 1458 mg/kg for *Ethmalosa fimbriata* and 923 and 103 mg/kg for *Pseudotolithus elongatus* (products from the improved smokehouse). Indeed, magnesium plays an important role in the normal functioning of cells, in the transmission of nerve impulses, and in the regulation of the heart rhythm. It stimulates the formation of antibodies, and is necessary in many systems, especially related to energy production.

Correlation of amongst parameters

Figure 5 further shows the matrix of correlation between parameters as earlier explained. Moisture content with time, ash with color, calcium with magnesium, calcium with wood volume, magnesium with wood volume, time with color, wood volume with efficiency, mass of CO_2 with efficiency, efficiency with texture and color with taste.

Versus	Moisture content (%)	Protein (%)	Ash content (%)	Calcium (mg/kg)	Iron (mg/kg)	Magnesum (mg/kg)	Time (hrs)	Wood volume used/sterre (m_3)	CO_2 emmitted (t/sterre)	Effciency	Colour	Texture	Taste
Moisture content (%)	1	**-0.814****	0.109	-0.205	-0.169	-0.100	**-0.489***	-0.242	-0.004	0.132	-0.149	-0.233	-0.240
Proteine (%)		1	0.026	0.205	0.238	0.160	0.322	0.230	0.062	-0.246	0.184	0.325	0.271
Ash (%)			1	-0.088	-0.076	-0.130	0.112	0.236	0.040	-0.213	**0.448***	0.085	0.297
Calcium(mg/kg)				1	-0.289	**0.917****	-0.063	**0.518****	0.146	-0.232	-0.055	0.081	0.139
Iron (mg/kg)					1	-0.188	-0.028	0.032	-0.068	-0.258	0.094	-0.040	0.176
Magnesimu(mg/kg)						1	-0.178	**0.630****	0.328	-0.278	-0.104	0.065	0.075
Time (hrs)							1	0.198	0.073	-0.004	**0.528****	0.013	0.388
Wood volume used/sterre (m^3)								1	**0.497***	**-0.603****	0.024	0.341	0.160
Mass of CO_2(t/sterre)									1	**-0.413***	0.228	0.260	0.135
Effciency										1	-0.057	**-0.495***	-0.021
Colour											1	-0.273	**0.666****
Texture												1	-0.215
Taste													1

Figure 5. Correlation Matrix of Parameters Used

Note. ** Significant (P<0.01), * Significant (P<0.05), Not significant (P>0.05) without asterisk.

4. Discussion

Some smoked fish quality parameters may be comparable to some available studies carried out. The high smoking time in traditional wood smoking is comparable to the results of Feka et al. (2009) who obtained an average of 21 hours. According to Ndoye (2000), the maximum formal moisture content that can be tolerated is 30%: the product must then have a normally compact and non-friable flesh texture. The low water content obtained in traditional smokehouses (average between 17.53% and 23.53%) for *Ethmalosa fimbriata* and between 9.77 and 21.68% for *Pseudotolithus elongatus* is comparable to that found by Nerquaye-Tetteh et al. (2002) after smoking *Chrysichthys auratus* with different types of wood (average between 9 and 13%). These results could be explained by a strong aeration of the firebox leading to a complete combustion and thus to an intense fire. Smoked products and especially fish are highly valued and remain an essential source of dietary protein (Patterson, 2005). The reduced protein contents obtained are close to those found by Essumank (1992) on smoked tilapia (67.5%). These products smoked on different smokehouses with different wood species would be a very good source of animal protein. These quantities of iron obtained are close to those found by Mujinga et al. (2009) on smoked *Oreochromis Niloticus* (2.613mg /kg)

Implications for efficient management and conservation of wood energy (dendro-bioenergy) adaptable to oven types while improving the quality of end product

Traditional oven uses more time, wood and lets out more CO_2 to obtain final product. Improved oven uses less time a small amount of wood and releases little CO_2. In general, the equipment used for traditional fish smoking is varied, but traditional smokehouses are the most dominant. Their configuration and use are not optimized. These smokehouses do not have a specific bottom, they are open on all sides, which makes heat transfer difficult. This has an impact on the quality of the final product and on the energy efficiency.

An improvement of the final product and the efficient management of lost energy would be to size the smokehouses, to close all the openings so as to leave only the one where the wood will be introduced in order to reduce the energy dissipation. Proper handling of the smokehouse can also improve both the quality of the smoked products and the energy yield by diversifying the energy sources (charcoal, sawdust); the conservation of charcoal obtained after several smoking operations could be used in another smoking operation and this at the beginning of the operation. This is to extract water from fish without smoke, flame and at moderate temperature until the desired weight loss. Smoking itself can take advantage of the remaining heat, by adding chips or sawdust slightly damp. Improvement of certain practices or operations in the smoking process such use mangrove Nypa plam (*Nypa fructicans*) fruits to slowing down heat can preserve quantities of certain species and may help reduce deforestation.

Smoking is a widespread technique in many African countries, of which about 80% of fish catches are smoked or dried in order to limit damage (Nsoga et al., 2020, and Tamgno et al., 2020). Many projects have introduced and disseminated various ovens generated by research since 1984 (Levesque, 1992; Mbengue, 1992; Deme, 1998; Deme, 2003; Feka et al., 2009) the results showing a maximium adoption rate of 22% in chokor with investments with little internal rate of return but sundry brigged ovens with maximum adoption rate of 37% generated an internal rate of return of 18% and a net present value of 21 million of FCFA (42000 US Dollars) (Dame, 2003). In Burkina Fasso for example, Kabré et al. (2003) observed by comparing three types of fish smoke ovens (Dafing and Monoclaire using traditional materials and chokor modern oven) that the quality of smoked fish depended on the type of oven with the chokor type giving more dehydrated smoked fish (72% moisture loss) than the traditional ones (Dafin, 65% and Monoclaire, 41%) but dafing and monoclaire were preferred for ease of availability of local materials and minimum amount of wood used from the nearby savanna dry forest.

5. Conclusion

Comparison of traditional and improved smokehouses using different types of wood show that: The volume of in land tropical forest species *Sacoglottis gabonensis* “Bidou”, *Albizia glaberrina* “Essack”, and that of mangrove *Rhizopora* spp “Matanda” wood used in the improved smokehouse is significantly lower than the volumes used in the traditional smokehouses. Smoking with the two species of forest wood in the improved smokehouses took lesser time than in the traditional smokehouse. On the other hand, smoking with mangrove wood in the traditional smokehouse took longer than in the improved smokehouse. *Ethmalosa fimbriata* and *Pseudotolithus elongatus* smoked in the traditional and improved smokehouses with the different species of wood used were of good quality from the point of view of protein, mineral salts and organoleptic. Water content obtained from the fish smoked with the traditional oven was reduced compared to the improved oven, which would make their transport and distribution difficult. The use of the two species of forest wood, *Sacoglottis gabonensis*, *Albizia glaberrina* provides the same product as with *Rhizophora racemosa*, the improved smoker provides a product of better quality from the point of view of water content than the traditional oven and also releases less CO_2.

Acknowledgements

The authors express their gratitude to the services of Conservation of Douala-Edea, the government department for Fisheries Mouanko and the District head, traditional authorities and people of the study villages for their participation in the study. Funding was from Netherlands Development Organization NOVIB to Cameroon Wildlife Conservation Society (CWCS). CWCS obtained the authorization from the Ministry of Wildlife and Forests (MINFOF) to work in the area.

References

AFNOR (Association Française de Normalisation). (1981). Recueil des normes françaises des corps gras. *Graines oleagineuses* (produits dérivés, 2rd ed., p. 438).

Ajonina, G. J. G., Kairo, G., Grimsditch, T., Sembres, G., Chuyong, D. E., Mibog, A. N., & FitzGerald, C. (2014). *Carbon pools and multiple benefits of mangroves in Central Africa: Assessment for REDD+* (p. 72). Retrieved from https://www.unep.org/pdf/REDDcarbon_lowres.pdf

Ajonina, G. N. (2008). Inventory and modeling mangrove forest stand dynamics following different levels of wood exploitation pressures in the Douala-Edea Atlantic coast of Cameroon, Central Africa. *Mitteilungen der Abteilungen für Forstliche Biometrie, Albert-Ludwigs-Universität Freiburg, 2008*(2), *215*. Retrieved from http://www.freidok.uni-freiburg.de/volltexte/6132/pdf/Gordon_N._Ajonina_Thesis.pdf

Ajonina, G. N. (2022). Cameroon Mangroves: Current Status, Uses, Challenges, and Management Perspectives. In S. C. Das, & E. C. Pullaiah, Ashton (Eds.), *Mangroves: Biodiversity, Livelihoods and Conservation*. Springer, Singapore. https://doi.org/10.1007/978-981-19-0519-3_21

Ajonina, G. N., & Eyabi, G. D. (2002). Saving Cameroon's mangroves through improved fish smoking houses: Cameroon Wildlife Conservation Society's community-based approaches in Douala-Edea mangroves. In Paper submitted to Mangrove Action Project, Los Angeles, USA (p. 11).

Ajonina, G., Timba, M., & Njie. F. (2020). *National Waterbird Census Report, Cameroon January 2020*. In M. van Roomen, G. Agblonon, T. Langendoen, G. Citegetse, A. Y. Diallo, K. Gueye, E. van Winden, & G. Luerssen (Eds.), *Simultaneous January 2020 waterbird and wetland census along the East Atlantic Flyway: National Reports. Wadden Sea Flyway Initiative p/a Common Wadden Sea Secretariat, Wilhelmshaven, Germany, Wetlands International, Wageningen* (pp. 96-99). The Netherlands, BirdLife International, Cambridge, United Kingdom.

Ajonina, P. U., Ajonina, G. N., Jin, E., Mekongo, F., Ayissi, I., & Usongo, L. (2005). Gender roles and economics of exploitation, processing and marketing of bivalves and impacts on forest resources in the Douala-Edea Wildlife Reserve, Cameroon. *International Journal of Sustainable Development and World Ecology*, *12*, 161-172. https://doi.org/10.1080/13504500509469627

AOAC (Association of Official Analytical Chemists). (1980). *Official Methods of Analysis* (13th ed., p. 978). Willian Horwitz edr, Washington.

CDM-ONFI-CWCS. (2009). *Protecting Cameroon estuary mangrove though improved smoke ovens—Project designing document clean development mechanism* (p. 62).

CWCS. (2001). *Cameroon Wildlife Conservation Society Douala-Edea Forest Project: Report of activities, Mounko, Cameroon* (p. 32).

Deme, M. (1998). Projet d'analyse du système de valorisation (transformation et commercialisation) des produits de la pêche artisanale dans les Etats membres de la Commission Sous-Régionale des Pêches (CSRP). In *Document de la CSRP, août 1998* (p. 17).

Deme, M. (2003). *Évaluation Economique De L'Impact De L'Adoption Des Fours Chorkor Et Des Fours Parpaing Dans La Transformation Artisanale Du Poisson A Joal Au Senegal*.

Djomo, A. N., Knohl, A., & Gravenhorst, G. (2011). Estimations of total ecosystem carbon pools distribution and carbon biomass current annual increment of a moist tropical forest. *Journal: Forest Ecology and Management*, *261*, 1448-1459. https://doi.org/10.1016/j.foreco.2011.01.031

Doat, J. (1977). Le pouvoir calorifique des bois tropicaux. *Revue Bois et Forêts Tropiques* (No. 172 Mars-Avril, 1977).

Essuman, K. M. (1992). *Le poisson fermenté en Afrique: Traitement, commercialisation et consommation FAO* (p. 80).

Eyabi Eyabi, G. D. (2010). *Fish smoking Training Manual for Stakeholders* (p. 12). Institute of Agricultural Research for Development, IRAD, Batoke-Limbe specialized station for fisheries research and oceanography.

FAO. (2004). Annuaire stastistique de la FAO (Vol. 11, p. 346).

Feamside, P. M. (1997). Wood density for estimating forest biomass in Brazilian, Amazonia. *For Ecol Manage*, *90*, 59-87. https://doi.org/10.1016/S0378-1127(96)03840-6

Feka, N. Z., Chuyong, G. B., & Ajonina, G. N. (2009). Sustainable utilization of mangroves using improved fish smoking systems: A management perspective from the Douala-Edea wildlife reserve, Cameroon. *Tropical Conservation Science*, *2*(4), 450-468. https://doi.org/10.1177/194008290900200406

Forkam, D. C., Ajonina, G. N., Ajonina, P. U., & Tchamba, M. N. (2020). Framework for assessing the level of stakeholders' involvement and governance in mangrove management: Case of selected local communities in the south west coastal Atlantic Region, Cameroon. *Journal of Ecology and The Natural Environment*, *12*(4), 150-164. https://doi.org/10.5897/JENE2020.0830

Fretey, J. (2021). Good news from Cameroon: The First Marine National Park. *African Sea Turtle Newsletter* (No. 17).

Husch, B., Beers, T. W., & Keuhaw Jr., J. A. (2003). *Forest mensuration* (4th ed., p. 443). John Wiley & Sons.

Kabré, A. T., Diarra, D., & Traoré, A. (2003). Le fumage du poisson au Burkina Faso: Comparaison des caractéristiques et de la rentabilité de trois types de fumoirs améliorés. *Cahiers Agricultures*, *12*(6), 409-417.

Knockaert, C. (1990). *Le fumage du poisson* (p. 174). Edition IFREMER, centre de Brest.

Levesque, P. (1992). Expérimentation de nouvelles techniques (four Chorkor) et améliorations de techniques existantes (pour Parpaing et au sol). *DTP no 8/ATEPAS* (p. 57).

Mbengue, M. (1992). Synthèse des expériences d'introduction des fumoirs Chorkor et Parpaing réalisées au Sénégal. *R.P./ATEPAS* (No. 22, p. 47).

MINAGRI. (2002). *Document de stratégie du secteur rural au Cameroun. Ministère de l'Agriculture, Yaoundé* (p. 212).

Mujinga, W., Mutala, S., & Hüsken, S. M. C. (2009). *Rapport d'analyse et table de valeur bromatologique de catégorie des poissons trouvés sur les marchés de poisson à Lubumbashi, République Démocratique du Congo*.

Ndoye, F. (2000). Aperçu de la filière halieutique au Sénégal. *Doc.Gret, Enda graf, Cnearc* (p. 21). Retrieved from https://www.infoconseil.sn/ressources.html

Nsoga, J. V. F., Milong, M. C. S., Nchoutpouen, N. M., Manz, K. J. C., Ekwalla, M. N. R. J., Tuem, S. R., ... Ndomou, M. (2021). Characterization of Smoking Activity and Perception of Smoked Fish by Households in the City of Douala (Cameroon). *International Journal of Nutrition and Food Sciences 2021*, *10*(6), 159-166. https://doi.org/10.11648/j.ijnfs.20211006.16

Patterson, J. (2005). Le fumage: Une technique idéale pour preserver la chair de mollusques. Canning of smoked brown mussel. *Perna indica. Phuket Marine Biological Center Special Publication*, *25*(1), 219-220.

Quinn, G. P., & Keough, M. (2002). *Experimental design and data analysis for biologists* (p. 527). Cambridge. https://doi.org/10.1017/CBO9780511806384

Tamgno, B. R., Vatsou, J., Zidiko, G., Goudoum, A., & Tinkeu, N. L. S. (2021). Protection des stocks de poissons secs en Afrique sub-saharienne. *Rev. Mar. Sci. Agron. Vét.*, *9*(4), 755-766.