Assogba et al., *Cogent Food & Agriculture* (2019), 5: 1641255
https://doi.org/10.1080/23311932.2019.1641255

cogent food & agriculture

Received: 22 May 2019
Accepted: 30 June 2019
First Published: 13 July 2019

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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Processing methods, preservation practices and quality attributes of smoked and smoked-dried fishes consumed in Benin

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Abstract: Field Investigations were carried out on traditional processing of fresh fish into smoked fish (SF) and smoked-dried fish (SDF) in southern regions of Benin. A total of 429 stakeholders were interviewed, and data were analysed using Sphinx survey plus2. Factorial Correspondence Analyses were performed with SPSS v16 to reveal both links between fish species, processing methods, and their distribution according to surveyed areas, and links between types of kilns and fuels used, and socio-cultural groups of processors. The results showed that SF and SDF were essentially produced by women (100%), and 32 species of fish were used for SF and SDF production. The smoking kilns used by processors were barrel kiln (67.7%), traditional kiln in clay (31.5%) and Chorkor (5.6%). The direct functioning mode of smoking kilns associated with the use of wood, plastic bags and kerosene as fuels could lead to the contamination of end-products by toxic molecules. Likewise, unsuitable preservation practices including the use of insecticide to prevent harmful

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PUBLIC INTEREST STATEMENT

This research was performed to investigate the processing methods, preservation practices, commercialization and quality attributes of smoked fish and smoked-dried fish. The research allowed to identify the major problems associated with smoking process and to determine upgrading actions that could be done to improve the sanitary quality of end-products. Indeed, smoking and smoking-drying processes, traditional kilns and fuel used for smoking were characterized. The direct functioning mode of traditional kilns was not suitable to protect processors from heat and smoke exposure and also could not ensure the safety of end-products. The public interest of this research is that it provides enough knowledge which could be useful to design and optimize improved equipment limiting chemical contamination of end-products by polycyclic aromatic hydrocarbons (PAH) of which benzo(a)pyrene (BaP) is known to be carcinogenic for human.

insect invasion could not ensure the safety of stored products. Therefore, it would be needful to upgrade both smoking kilns and preservation practices to ensure the safety of processed fish.

Subjects: Food Chemistry; Food Engineering; Food Laws & Regulations

Keywords: fish; smoking kilns; fuel; chemical hazard; storage practices

1. Introduction

Fish and fish products play a considerable role in food supply in West African countries where 15–20% of all animal proteins consumed are from aquatic sources (Food Agriculture Organization [FAO], 2000). Because of its perishability, fresh fish is particularly difficult to preserve in tropical countries due to deficiency of adequate equipments, climatic and environmental conditions which contribute to fish spoilage within few hours (Anihouvi, Hounhouigan, & Ayernor, 2005). To limit post-capture loss, various preservation methods such as frying, fermentation, drying, salting and smoking are used individually or in association (Anihouvi et al., 2005; Issa, Mopate, & Missohou, 2012; Yacouba, 2009). These methods aim to inactivate micro-organisms and endogenous enzymes which are involved in the spoilage mechanism.

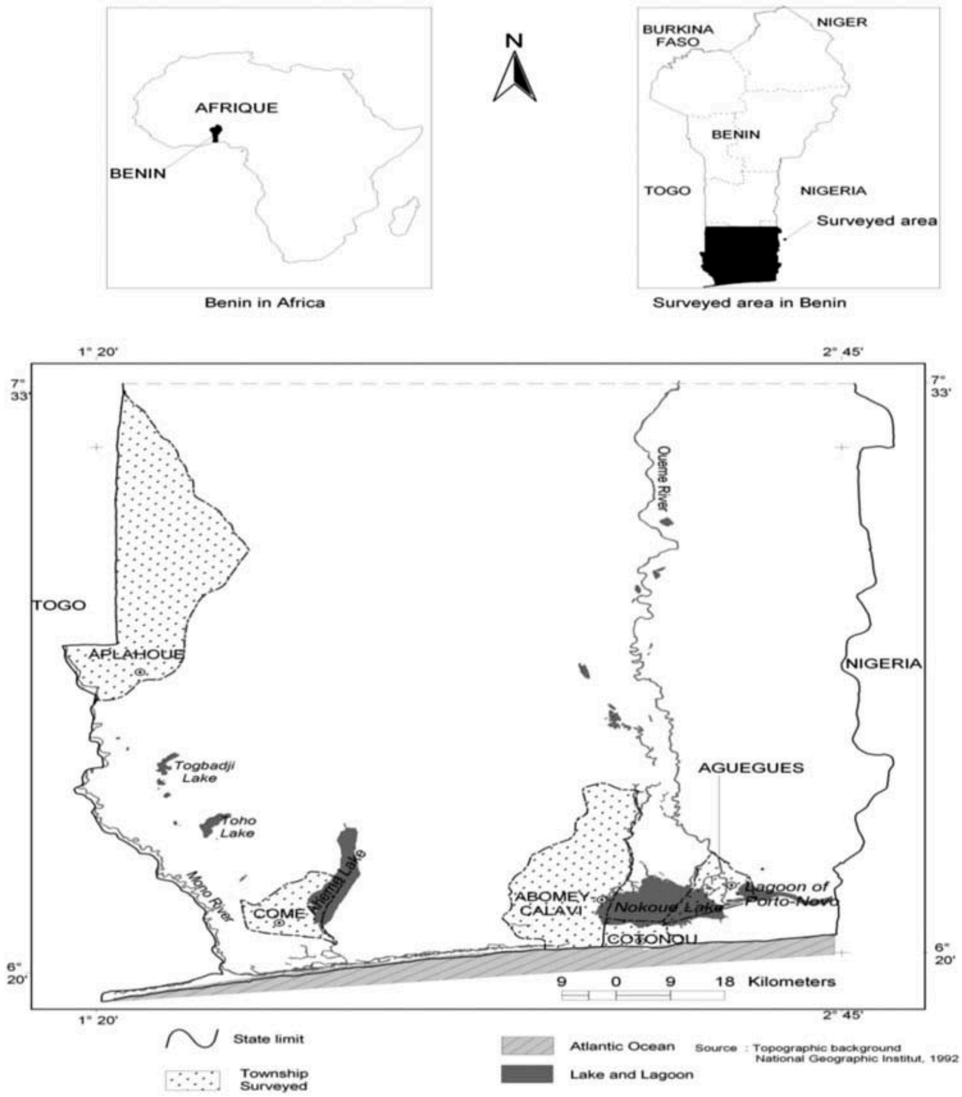
In Benin, smoking is one of the most used traditional methods for fish preservation (Aremu et al., 2013). According to Škaljac et al. (2018), smoking involves submission of food such as fish to direct or indirect action of smoke during incomplete combustion of certain tree species used as fuels. Smoking process improves organoleptic characteristics and induces water loss and reduction of the microbial load of foods due to heat, aromatic and bactericidal substances of smoke, thus predisposing them to better conservation (Igwegbe, Negbenebor, Chibuzo, Badau, & Agbara, 2015; Yusuf et al., 2015). However, the conditions of processing, storage and selling could subject smoked fish to chemical and microbial contamination. Indeed, chemical hazard such as Polycyclic Aromatic Hydrocarbons and pathogenic bacteria such as *Escherichia coli, Staphylococcus aureus, Bacillus cereus* and *Salmonella* have been detected in smoked fish (Ali, Ahmadou, & Mohamadou, 2011; Ineyougha, Orutugu, & Izah, 2015; Nunoo & Kombat, 2013; Olai, Koffi, Koussemon, Kakou, & Kamenan, 2007). According to Duedahl-Olesen, Christensen, Højgardc, Granby, and Timm-Heinrich (2010), chemical compounds generated by wood combustion during smoking are transferred to smoked products. Consequently, smoked fish consumption may result in a public health problem. Thus, all quality improvement strategy requires an inventory of stakeholders' practices and end-product quality perception. The present study, performed through a field survey, investigated the indigenous practices of processing of fresh fish into smoked fish (SF) and smoked-dried fish (SDF), the raw materials used, the quality attributes as perceived by the stakeholders, and the main constraints related to the processing and the storage of smoked products.

2. Material & methods

2.1. Survey areas and sampling of actors

The survey was carried out in the municipalities of Aguégués, Cotonou, Abomey-Calavi, Comé and Aplahoué located in Ouémé, Littoral, Atlantic, Mono and Couffo Districts, respectively (Figure 1). These districts were identified to be the main fishing and fish processing areas located around the main lakes (Nokoué and Ahémé), Lagoon (Porto-Novo) and Atlantic Ocean as reported by Gnimadi et al. (2006), Chabi et al. (2013) and Kpodékon et al. (2014). The number of actors (processors and traders) interviewed was determined according to Dagnelie (1998). A total of 429 stakeholders (124 processors and 305 traders) of SF and SDF from various social-cultural groups and of both genders at different ages were randomly interviewed in the survey zones.

Figure 1. Benin map showing the surveyed areas.



2.2. Data collection

The survey was conducted by individual interviews and focus group discussions with processors and traders using a questionnaire, and observations of processors at work. A preliminary survey was conducted in order to identify production sites and to pre-test the questionnaire. The interviews were conducted in French and local languages (*Goun, Fon, Mina* and *Adja*).

2.3. Data analysis

Descriptive statistics were performed on the collected data using Sphinx survey plus2 (version 4.5) software. Factorial correspondence analysis (FCA) was performed using SPSS (version 16.0) to reveal the links between fish species and the different processing methods, and between fish species and the surveyed areas. FCA was also used to describe the links between socio-cultural groups, types of kilns and fuels used for processing.

Table 1. Socio-cultural profile of actors (%)

Characteristics	Processors (n = 124)	Traders (n = 305)
Age (years)		
<20	0.8	3.0
20–30	17.7	21.0
31–40	38.7	37.0
41–50	25.8	22.3
51–60	9.7	9.2
> 60	7.3	3.6
Gender		
Female	100	100
Male	0	0
Socio-cultural groups		
Fon	19.4	11.8
Goun	16.1	16.7
Mina	15.3	8.2
Adja	12.1	23.0
Pédah	11.3	21.3
Aïzo	11.3	2.3
Xlwa	9.7	7.5
Tori	1.6	3.3
Toffin	1.6	2.0
Nago	0.8	0.3
Sètô	0.8	1.0
Yoruba	0	1.0
Watchi	0	0.7
Wouémè	0	1.0
Mahi	0	0.3
Educational level		
Primary school	8.9	16.1
Secondary school	6.5	11.1
University	0	0
Illiterate (no formal education)	82.3	70.5
Local languages education	2.4	2.3
Marital status		
Unmarried	0.8	4.6
Married	99.2	93.1
Religion		
Animism	14.4	21.5
Christianism	83.2	78.1
Islam	2.4	0.4
Years of experience		
<10	31.5	-
10–25	50	-
>25	18.5	-

(*Continued*)

Characteristics	Processors (n = 124)	Traders (n = 305)
Access mode to smoking knowledge		
From their parents	82.2	-
Learning with a processor	13.7	-
Self-taught person	4	-
Reasons justifying actor activity		
Inherit from parents	54.5	-
Source of income	45.5	-

3. Results & discussion

3.1. Socio-cultural profile of processors and traders

The socio-cultural profile of the respondents is presented in Table 1. All SF and SDF processors interviewed (100%) were female. Majority (82.2%) of the processors surveyed were aged between 20 and 50 years of age; 64.5% ranged from 31 to 50 years of age, while 17.7% ranged between 20 and 30 years of age, and 17% had more than 50 years old. There are Christians (83.2%), animists (14.4%) and muslims (2.4%), belonged to various socio-cultural groups including *Fon* (19.4%), *Goun* (16.1%), *Mina* (15.3%), *Adja* (12.1%), *Pédah* (11.3%), *Aîzo* (11.3%) and *Xwla* (9.7%), followed by minority groups of *Tori* (1.6%), *Toffin* (1.6%), *Sètô* (0.8%) and *Nagot* (0.8%) (Table 1). Majority (84.7%) had no formal education (illiterate and local language education), while 8.9% and 6.5% of them had primary and secondary education, respectively (Table 1). Many of them (79%) produced smoked fish (SF) against (21%) that produced smoked-dried fish (SDF) (Table 1). About 68.5% of processors interviewed had at least 10 years experience in SF and/or SDF production, 50% and 18.5% of them had between 10 and 25 years, and more than 25 years' experience, respectively (Table 1). Eighty-two per cent (82.2%) of processors interviewed received smoking knowledge from their parents, 13.7% received it by learning with a processor, while only 4% acquired smoking practice by self-taught. The results showed that the smoking activity is mainly practiced by young women of between 31 and 50 years old. This confirms the difficulty to carry smoking activity beyond 50 years of age, because of cutaneous, ophthalmological, pulmonary and cardiac diseases that occurred, due to the exposure to smoke, gases and heat as claimed by processors surveyed. Indeed, these results closed to those reported by Agodokpessi et al. (2011) who found that 60% of smoked fish processors from Hwlacodji (Benin) were women that aged between 21 and 40 years, and many of them (83%) had at least one respiratory symptom such as rhinitis (77%), cough (70%) and dyspnea (65%). The results also showed that majority of processors (82.3%) are illiterate (no schooling) and this could influence negatively the safety of their product due to lack of good hygiene practices during the processing of fresh fish into smoked and smoked-dried fishes.

Similarly, all the traders of SF and SDF interviewed were female (100%). Fifty-nine per cent of them (59.3%) were aged between 31 and 50 years of age, 21% were between 20 and 30 years of age, while only 12.8% were older than 50 years (Table 1). The trade of SF and SDF is practiced by various socio-cultural groups including mainly *Adja* (23.0%), *Pédah* (21.3%), *Goun* (16.7%) and *Fon* (11.8%) (Table 1). Most of traders interviewed (70.5%) had no formal education and 93.1% of them are married.

3.2. Traditional production of smoked and smoked-dried fishes

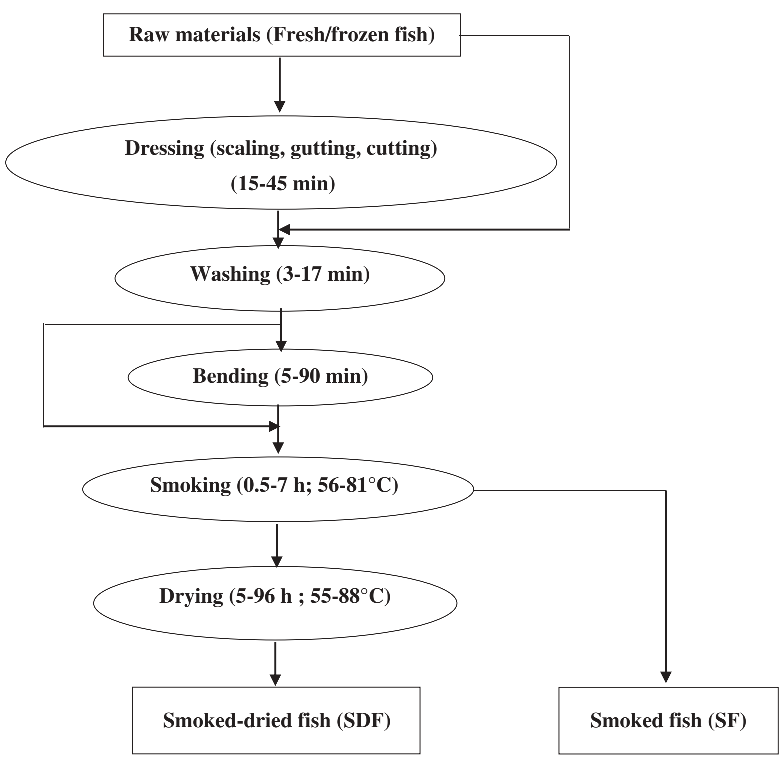
3.2.1. Types of fish used as raw materials

The types of fish used for the production of SF and SDF included fresh fish caught from local water (claimed by 33.1% of processors) and imported frozen fish (claimed by 66.9% of processors). The main reasons justifying the use of fresh fish are related to its availability (claimed by 63.4% of processors), its physical accessibility (asserted by 19.5% of processors) and consumer preference (claimed by 7.3% of processors), while 9.8% evoked any reason for its use. Frozen fish is also used because of its availability, its physical accessibility, its preference by consumers and ease of selling of the end-product (claimed by 42.2%, 36%, 16.9% and 4.8% of processors, respectively). Various fish species (n = 32 species) were used for SF and SDF production. Among these fish species, the most frequently used to produce smoked fish (SF) were *Scomber scombrus* (claimed by 71% of processors), *Trachurus trachurus* (62.1%), *Merluccius polli* (25.8%), *Dentex canariensis* (16.1%) and *Oreochromis niloticus* (15.3%), while *Cypselurus cyanopterus* (22.6%), *Clupea harengus* (19.4%), *Sphyraena baraccuda* (13.7%), *Sardina pilchardus* (13.7%), *Ethmalosa fimbriata* (12.1%) and *Sardinella maderensis* (10.5%) were used for the production of smoked-dried fish (SDF). Criteria used by processors for raw fish quality appreciation were the brightness of the skin (claimed by 44.4% of processors), the hardness (43.5%), the red colour of gills (33.1%) and the eyes brightness and transparency (29%). Depo, Dossou, and Anihouvi (2015) have also reported that processors use similar sensorial criteria to assess the freshness of fish before purchasing.

3.2.2. Processing of fresh fish into smoked and smoked-dried fishes

Fresh fishes from lakes and lagoons were generally scaled, gutted and washed on the banks of rivers before transportation to the processing sites. They were kept on vegetable trays or smoking grill in the shade at quite aerated place before being smoked. The average duration between purchase time and processing time as claimed by processors interviewed was 1.93 ± 3.15 h and 2 ± 4.12 h for frozen fish and fresh fish, respectively. These waiting times before processing of fresh or frozen fish coupled with a high ambient temperature (28 ± 2°C) and unsanitary conditions could lead to fast fish spoilage (Huss, 1999). When the time before processing is more than those indicated above, 3.2% of processors interviewed claimed to use ice to extend the preservation of fresh fish. Some of them (28.2%) claimed to maintain the frozen fish in the shop packaging, while 22.5% of them kept the frozen fish in covered bowl or in basket covered with cloth in order to preserve fish before processing.

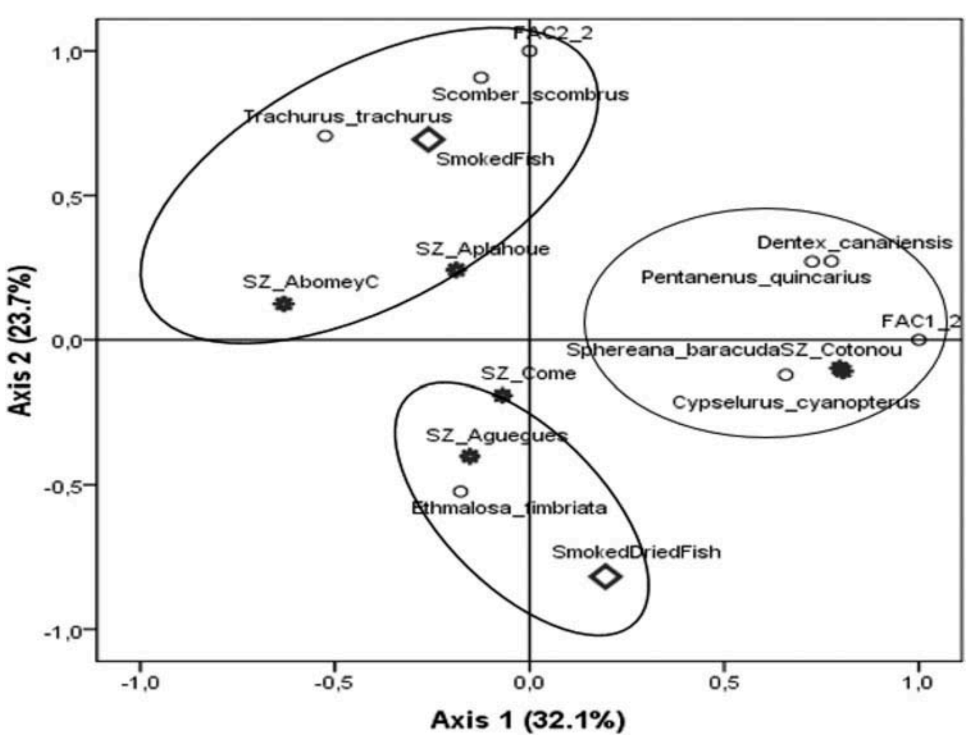
Figure 2. Flow diagram of production of smoked and smoked-dried fishes.



With the exception of 21% of processors surveyed who are specialized in the processing of fresh fish into smoked and smoked-dried fishes, the majority of processors interviewed (79%) produced only smoked fish. Figure 2 shows the flow diagram of smoked and smoked-dried fish production. The processing methods vary with fish species and fish size. The dressing (scaling, gutting and cutting) and the bending of fish are not systematic. Their achievement depends on several considerations. Scaling is generally done when fishes are intended for smoking but not for smoking and drying. It is the case of *O. niloticus, D. canariensis, M. cephalus* and *C. cyanopterus* contrary to fish species such as *E. fibriamta, S. maderensis* and *C. harengus* which are intended for smoking-drying. Cutting is done when the fish has a big size. Gutting it is not done on species like *S. scombrus, T. trachurus*, and *M. polli* for which it would affect the presentation of the end-product. According to 79% of processors surveyed (n = 98 respondents), the smoking duration varies between 0.5 and 7 h with an average time of 2.4 ± 1.5 h, and depends essentially on two parameters including the size of fish and both the intensity of heat and smoke from the fireplace. This average time is closed to 2.5 h reported by Rivier et al. (2010) for kong (*Arius heudelotti*), a smoked fish produced in Senegal. According to dried fish processors, the drying step lasted from 5 to 96 h (n = 26 smoked-dried processors) with an average duration of 43 ± 30 h which represents the double of drying time of 26 h reported by Rivier et al. (2010). The main indicators used by SF processors to appreciate the end of smoking process were the golden colour of fish, the change of texture, the process duration and the odour of product (claimed by 60.4%, 32.7%, 5.9% and 1% of SF processors, respectively). According to them, the golden colour associated with the brightness of fish skin makes the end-product more attractive to consumers. Furthermore, change of colour and dry texture of fish were evoked by 47.8% and 43.5% of SDF processors as the indicators of the end of smoking-drying process. The major problems faced by smoked fish and smoked-dried fish processors (100%) are related to exposure to heat and smoke released by the smoking kiln during the processing.

The factorial correspondence analysis (FCA) was performed to reveal the links between the most fish species used, the processing technologies of SF and SDF, and the predominant areas of use (Figure 3). The two axes obtained accounted for 55.8% of the total variation of which 32.1% was

Figure 3. Factorial correspondence analysis to reveal links between fish species, processing technology and their distribution according to surveyed areas. SZ = Surveyed zone; SmokedFish = smoked fish technology; SmokedDriedFish = smoked-dried fish technology.



explained by the first axis (Axis 1) and 23.7% by the second axis (Axis 2). Fish species mostly used for each processing method were grouped together with the technology. Among 12 fish species mostly processed, seven (07) showed correlation with processing technologies and their relative predominance areas. Thus, fish species including Saloumon (*Scomber scombrus*) and Silivi (*Trachurus trachurus*) were mostly used for smoked fish production technology mainly in Abomey-Calavi and Aplahoué municipalities while Cheke (*Ethmalosa fimbriata*) was used for smoked-dried fish production technology in Aguegues municipality. The smoked-dried fish made from Lizi (*Sphyraena baraccuda*) and Avion (*Cypselurus cyanopterus*) and the smoked fish obtained from Sicasica (*Dentex canariensis*) and Capitaine (*Pentanenus quinquarius*) were mainly produced in Cotonou municipality.

3.2.3. Types of kilns and fuels used for processing

Three main types of kiln including traditional kiln made in clay, barrel kiln and Chorkor kiln were used by smoked and smoked-dried fish processors. These kilns had the same functioning mode. The fishes spread on the metal smoking tray are directly exposed to smoke and heat produced below and this contributed to PAHs contamination as indicated by Codex Alimentarius Commission [CAC] (2009). The direct smoking process also enabled the dropping of fat in fireplace and its combustion. This phenomenon is known to be an important factor which contributed to PAHs production during meat grilling as reported by Viegas, Novo, Pinto, Pinho, and Ferreiraa (2012). The most used kilns are barrel and traditional kilns. The barrel kiln is known by 91.1% of processors surveyed but used by 67.7% of them. It is the most used in the municipalities of Cotonou (84.6%), Comé (66.7%) and Abomey-Calavi (64%). The traditional kiln is known by 59.7% of processors interviewed of whom 31.5% of respondents are users in all the study areas. This type of kiln is more encountered in Aplahoue (61.5% of respondents), Comé (50%) and Abomey-Calavi (40%) municipalities. Chorkor kiln is known by 19.4% of processors, used by 5.6% of them and it is observed only in the municipalities of Aguégués and Aplahoué. These results are similar to those reported by Degnon et al. (2013) who observed that shrimp processors used four main kilns (barrel kiln, Chorkor kiln, traditional kiln and parallelepiped kiln) of which the most used was barrel kiln (claimed by 95% of shrimp processors). Investigations carried out by Depo et al. (2015) on fish processors also revealed that the most used kiln was barrel kiln (80%) followed by traditional kiln (20%); Chorkor kiln was known but not used by the surveyed processors.

Table 2. Tree species used by SF and SDF processors

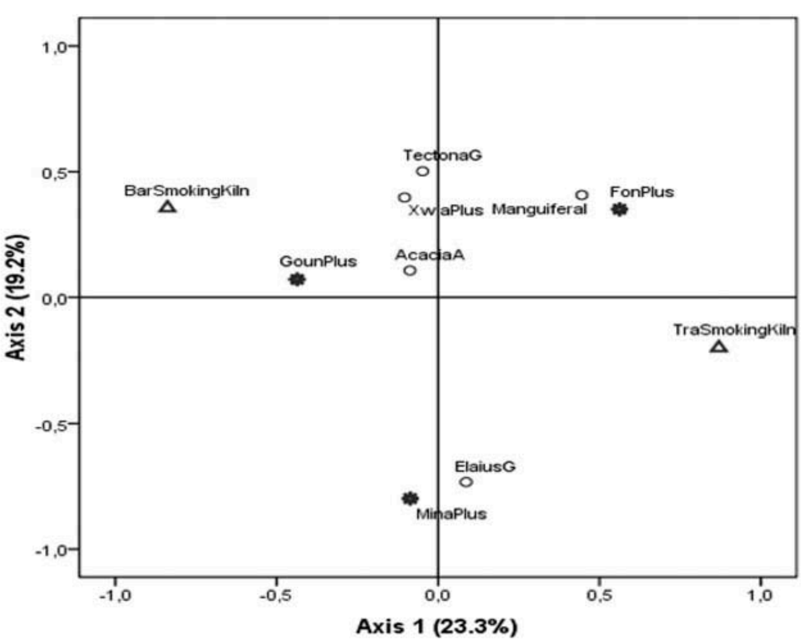
Common name of tree species	Scientific name	Processors (%)
Pencil tree	*Acacia auriculiformis*	64.5
Teak tree	*Tectona grandis*	45.2
Coconut raid	*Coconut nucifera*	35.5
Mango tree	*Mangifera indica*	29.0
Palm tree	*Elaeis guineensis*	13.7
Australian pine tree	*Casuarina equisetifolia*	12.1
Neem tree	*Azadirachta indica*	9.7
Wrong kola tree	*Garcinia kola*	5.6
River redgum tree	*Eucalyptus camaldulensis*	2.4
Cashew tree	*Anacardium occidentalis*	2.4
Guava tree	*Psidium guajava*	1.6
Red mangrove tree	*Rhizophora racemosa*	1.6
African oak tree	*Milicia excelsa*	0.8
Birch-tree	*Anogeissus leiocarpa*	0.8

The most used fuel is wood (claimed by 94.4% of processors surveyed). Various wood species are used for fish smoking and smoking-drying, but *A. auriculiformis* (64.5%) and *Tectona grandis* (45.2%) are the mainly used, followed by *Coconut nucifera* (35.5%), *Mangifera indica* (29.0%), *Elaeis guineensis* (13.7%) and *Casuarina equisetifolia* (12.1%) (Table 2).

Wood from all of these tree species, except *Elaeis guineensis* were also used for shrimps smoking in Benin with *A. auriculiformis* as the most used fuel (claimed by 45% of smoked shrimp processors) (Kpoclou, Anihouvi, Scippo, & Hounhouigan, 2013). According to fish processors (n = 106) interviewed, these wood species are used because of their availability (20.8% of respondents), good combustion (70.8% of respondents) and selling cost (10.4% of respondents). However, *Tectona grandis* was considered as a bad fuel by processors because it produces black smoke which is injurious for the colour and the brightness of the processed fish. Other fuels are also used in association with wood according to their availability and the production target. These ones include wood shaving (used by 41.9% of processors surveyed), coconut shell (33.1%), cardboard (25.8%), palm nut crab and shell (22.3%) and sugar-cane scratch (21%). Maize spathe and cob (8.9%), manioc peel (3.2%), kerosene (2.4%), coconut branch (2.4%), orange dried peel (1.6%), peanut shell (1.6%) and plastic bags (0.8%) are less used as fuels by the processors. During smoking step, wood shaving and cardboard are wetted and introduced in the fireplace in order to attenuate the intensity of flame and generate more smoke, an essential component for fish smoking. This intentional production of smoke could improve the sensory characteristics of end-product if smoke was produced moderately (Stolyhwo & Sikorski, 2005). According to processors, sugar-cane scratches give a golden and attractive colour to the end-product. The use of kerosene and plastic bags by few numbers of processors to light fire is still significant since the toxic molecules emanating from their combustion could be present in the flames or smoke and contaminate fish during smoking (Oanh, Rdh, & Dung, 1999). Oanh, Ngnghiem, and Phyu (2002) proved that kerosene was the highest emission factor of 11 genotoxic PAHs in smoke samples at gas phase while the total toxicity emission factor was the highest from sawdust briquettes, followed by kerosene and wood fuel.

The factorial correspondence analysis (FCA) (Figure 4) performed to investigate links between the most used smoking kilns and the most used fuels, and the relations between the most used smoking kiln and socio-cultural groups revealed that the barrel kiln is used either with

Figure 4. Factorial correspondence analysis to reveal links between types of kilns and fuels used, and socio-cultural groups of processors. BarSmokingKiln = Barrel smoking kiln; TraSmokingKiln = Traditional smoking kiln; TectonaG = *Tectona grandis*, ManguiferaI = *Manguifera indica*, AcaciaA = *Acacia auriculiformis*; GounPlus = *Goun and similar*; MinaPlus = *Mina and similar*; XwlaPlus = *Xwla and similar*; FonPlus = *Fon and similar.*



A. auriculiformis or *T. grandis* as fuels while the traditional kiln is used with *M. indica* and *E. guineensis*. The main socio-cultural groups including Goun, Xwla, Fon and Mina used *A. auriculiformis, T. grandis, M. indica* and *E. guineensis* as fuels, respectively. This is in accordance with the availability of these fuels in the located areas of different socio-cultural groups.

3.2.4. Storage and problems related to storage of SF and SDF

Usually, all the processed fish is not sold the same day. Most of smoked fish processors (76%) claimed that their products can be stored during 1–3 days. Also, all the surveyed traders (100%) asserted that smoked fish can be preserved for 1–3 days, with an average storage time of 2.4 days corresponding to 58 h, whereas smoked-dried fish can be stored during 7–365 days, with an average time of 78 days according to fish species. However, most of smoked-dried fish processors (60% of respondents) estimated that their products could be stored up to 90 days whereas 32% of them claimed that they stored their products between 31 and 90 days. Beyond three days, smoked fish loses its commercial value, and this negatively influences the margin profit of processors. Nevertheless, some smoked fish processors (19%) stored their product between 4 and 7 days when unsold smoked fish are subjected to a moderate heat treatment at the end of each day. The next day, such fish is rinsed with water, cleaned using a rag with vegetable oil (palm oil, peanut oil or mixed of both), and heated again to make it shine and attractive to customers. Jallow (1995) reported that fish at 10–15% moisture content, had a shelf-life of 3–9 months when stored properly. In the same manner, Civera, Parisi, Amerio, and Giaccone (1995) reported that the shelf-life of smoked Atlantic and smoked Canadian salmon were about 40–50 days and 80 days if they were kept at 2–3°C, respectively. The low storage time (1–3 days) reported in this study for smoked fish could be due to the least drying level, the lack of hygiene in handling and inadequate storage conditions. Processed fishes (SF and SDF) stored at ambient temperature (28 ± 2°C). Smoked fish are most of the time packaged in basket covered with cement paper (claimed by 50.5% of SF processors), on smoking grid covered with paper board or old clothes (35.6% of SF processors), in basket covered with old clothes (8.9% of SF processors) and in basket covered with another basket (4.9%). Similarly, smoked-dried fish are also packaged in basket covered with cement paper (78.3% of SDF processors), on smoking grid covered with paper board or old clothes (17.4%) and in basket covered with another basket (4.3%). These storage practices constituted good conditions for the increasing of spoilage bacteria in the end-products. The storage problems associated with smoked fish are related to the development of unpleasant odour (claimed by 58.3% of SF processors versus 33.3% of traders), the rot of product (25% of SF processors versus 50% of traders) and the presence of maggots (16.7% of SF processors), while smoked-dried fish is mainly subjected to insect attack (claimed by 66.7% of SDF processors versus 53.3% of traders) and rot of product (33.3% of SDF processors versus 13.3%). Others problems associated with the storage of SDF are related to attack by moulds and increase of moisture content. To solve these storage problems, various treatments are applied by the stakeholders of SF and SDF. Majority of surveyed traders (87.5%) re-dry the product (SF and SDF) under soft heat treatment while some traders expose the product to sun-drying (37.5%). Among the traders of SDF who evoked insect attack, 55.5% and 11.1% used insecticide and red chilli to treat the storage room, respectively. The use of insecticide to prevent harmful insects' invasion could be an additional risk to consumers.

3.3. Commercialization of SF and SDF

The most smoked fish marketed are the ones obtained from *Scomber scombrus* (claimed by 36.1% of traders), *Trachurus trachurus* (34.1%) and *Oreochromis niloticus* (27.9%), while *Engraulis encrasicolus* (33.1%), *Ethmalosa fimbriata* (19.7%), *Sardinella maderensis* (17.0%) and *Cypselurus cyanopterus* (14.4%) are the most marketed smoked-dried fish. These fish species belong to species fished in the survey areas except *Engraulis encrasicolus* which is imported from Ghana and Togo. The average selling prices of some SF and SDF were estimated. With the exception of *Oreochromis niloticus* which cost a rough average purchase price of 5.4 US$/kg (1 US$ = 555.57 CFA), the other smoked fishes were less expensive than smoked-dried fish species. The rough average selling prices of smoked fish from *Scomber scombrus, Trachurus trachurus, Clupea harengus* and *Merluccius polli* ranged between 2.6 and 4.2 US$/kg, while those of smoked-dried fishes varied from 5.3 to 10.5 US $/kg. Among the smoked-dried fishes species, *Sphyraena baraccuda* was the most expensive (10.5 US$/kg).

3.4. Quality attributes of SF and SDF according to stakeholders

Quality appreciation of smoked and smoked-dried fishes by processors and traders is mainly based on sensory attributes such as texture, colour, taste and odour. Other quality criteria such as drying level, fish size and cooking level were mentioned by some stakeholders. Most of smoked fish processors (80.7%) and smoked-dried fish processors (50%) and traders of the two types of processed fish (44.82%) used colour to appreciate their product. About 52.84% of traders claimed that taste is an important quality attribute for SF while 76.9% of smoked-dried fish processors and 34.11% of traders asserted that SDF should have high drying level to assure long shelf life. Texture is also taken into account by 31.1% of smoked fish processors, 23.1% of smoked-dried fish processors and 23.08% of traders.

4. Conclusion

The study revealed that smoking process varied according to fish species and type of end products expected. Thus, some smoked fish can be preserved for few days while other species are smoked and dried for long shelf-life. The wood from *A. auriculiformis* was the main fuel used by processors and the barrel kiln was the most used due to facility of its use, less fuel consumption, short duration of smoking, accessibility at lower cost, less cumbersome and durability. Quality attributes used for SF and SDF are based on taste, colour, texture, degree of drying and odour. The major problems faced by processors are related to the exposure to heat and smoke released by the smoking kiln. The main storage problems evoked by stakeholders for both smoked fish and smoked-dried fish are related to insect attack, emission of unpleasant odour, rot of products and attack by mould. Further study needs to be undertaken to assess and improve the processing and preservation methods of SF and SDF in accordance with the sensorial attributes as expected by consumers.

Funding
This work was supported by Belgium Government through QualiSani Project/PRD-ARES-CCD.

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Competing Interests
Authors declare no competing interests.

Citation information
Cite this article as: Processing methods, preservation practices and quality attributes of smoked and smoked-dried fishes consumed in Benin, Mahunan François Assogba, Dona Gildas Hippolyte Anihouvi, Ogouyôm Herbert Iko Afé, Yénoukounmè Euloge Kpoclou, Jacques Mahillon, Marie-Louise Scippo, Djidjoho Joseph Hounhouigan & Victor Bienvenu Anihouvi, *Cogent Food & Agriculture* (2019), 5: 1641255.

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