Effect of fuel wood type on the quality of smoked fish - *Chrysichthys auratus*

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ABSTRACT

The effects of wood fuel from four trees, *Terminalia avicennoides*, *Anogeissus leiocarpus*, *Combretum ghasalense* and *Pterocarpus erinaceus*, on the quality of smoked *Chrysichthys auratus* were assessed by evaluating the chemical and microbiological quality of the smoked fish samples. Proximate analysis for the major nutritional constituents of fish muscle yielded an average of 50.6 per cent protein, 23 per cent fat, and 14.5 per cent ash. The results confirmed that the smoked fish samples were of good nutritional quality. They were good sources of calcium and iron. However, fat levels were high, and may cause rancidity problems within a short period of storage. The moisture content (average 10.6 %) was low enough to present little deterioration problems under controlled storage conditions. Microbial populations decreased considerably during smoking, but were not completely eliminated. *Staphylococcus* sp. and *Salmonella* sp. were absent in all the smoked fish samples. The smoking process was, therefore, effective in improving the microbial quality of the smoked fish.

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RÉSUMÉ

NERQUAYE-TETTEH, G. A., DASSAH, A. L. & QUASHIE-SAM, S. J.: *Effet de type de bois de feu sur la qualité de poisson fumé* – Chrysichthys auratus. Les effets de bois de feu de quatre arbres à savoir: *Terminalia avicennoides, Anogeissus leiocarpus, Combretum ghasalense* et *Pterocarpus erinaceus* sur la qualité de *Chrysichthys auratus* fumé étaient estimés par l'évaluation de qualité chimique et microbiologique des echantillons de poisson fumé. Analyse immédiate pour les éléments constitutifs alimentaires majeurs de muscle de poisson rendait un moyen de 50.6 pour cent de protéine, 23 pour cent de graisse et 14.5 pour cent de cendre. Les résultats confirmaient que les échantillons de poisson fumé étaient de bonne qualité alimentaire. Ils étaient de bonnes sources de calcium et de fer. Les niveaux de graisse étaient toutefois élevés et pourraient créer des problèmes de rancissement dans une brève période de stockage. Le contenu d'humidité (10.6 % au moyen) était assez basse pour présenter peu des problèmes de détérioration sous les conditions de stockage réglées. Les populations microbiennes diminuaient considérablement pendant le fumage mais n'étaient pas complètement eliminées. *Staphylococcus* sp. et *Salmonella* sp. étaient absents dans tous les échantillons de poisson fumé. Le processus de fumage était, donc, efficace pour l'amélioration de la qualité microbienne du poisson fumé.

Introduction

In Ghana, fish smoking is one of the most widely used traditional fish-processing methods. Studies on fish consumption patterns in Ghana show that fish is consumed more in the smoked form (Orraca-Tetteh & Nyanteng, 1971; Plahar, Nti & Steiner-Asiedu, 1995, 1996, 1997). It is estimated that 80 per cent of processed fish is smoked.

Various species of fish are smoked, depending on availability. *Chrysichthys* species are among the most commonly caught and smoked freshwater fish in Ghana where there are seven known species in various water bodies. *Chrysichthys auratus* occurs in the Volta Lake, *C. walkeri* in the Pra Basin, *C. maurus* from the Bia, Tano and Pra Basins, *C. johnelsi* in the Bia and Tano Basins, and *C. nigrodigitatus* occurs widely (Dankwa, Abban & Teugels, 1999).

Fuel wood is the main source of energy for fish smoking. Although many wood types may be used as fuel for fish smoking, among the many factors influencing the choice of wood, what is used depends on local availability. The fuel wood preferences of most fish smokers are also related to the physical characteristics of the wood and how they affect the smoked product (Kordylas *et al.*, 1982; Nerquaye-Tetteh, 1985; Lartey, Asiedu & Okeke, 1994). Different fuel woods may affect the quality of the smoked fish differently.

The organic constituents of wood are reported to include cellulose, hemicellulose, and lignin. When wood is burnt, the chemical compounds of which it is formed are broken down into many smaller compounds as a result of incomplete combustion (Cutting, 1965; FAO, 1970; Storey, 1982; Wheaton & Lawson, 1985). The characteristics of traditionally smoked products are to some extent dependent on the source of the smoke. A study on smoking fish with Eucalyptus wood in Zambia showed that the smoked product was golden-brown, and had a desirable texture as well as an appealing smoky aroma. There was no bitter taste when eaten, and the product could sell well (Mwambazi *et al.*, 1995). Mensah (1988) also observed that some of the smoked fish from the Volta Lake in Ghana, which are black and unattractive, are normally not due to charring but to the type of fuel wood used.

Wood smoke is composed of vapours and particles that are easily taken up by moisture on the fish surface during smoking, and they contribute to the characteristic smoke smell and colour (Foster, Simpson & Campbell, 1961; Gilbert & Knowles, 1975; Hamm, 1977; Daun, 1979). In addition to smoke imparting colour and flavour-enhancing ingredients to the smoked product, it also has anti-oxidative and bactericidal properties (Barylko-Pikielna, 1977).

Fish smoking has been practised over the years in Ghana and the fuel woods used are well documented (Kordylas *et al.*, 1982; Nerquaye-Tetteh, 1985; Asare & Osei Bonsu, 1993; Lartey *et al.*, 1994). However, the effect of wood smoke on smoked fish is poorly documented.

The objective of this study was to determine how four species of fuel wood used for fish smoking affect the smoked product by evaluating the chemical, microbiological, and sensory quality of the smoked fish.

Materials and methods

The study was undertaken in the Sene District of the Brong Ahafo Region of Ghana, where fish smoking is a major economic activity. The four fuel wood trees used for the study are *Terminalia avicennoides*, *Anogeissus leiocarpus*, *Combretum ghasalense*, and *Pterocarpus erinaceus*, which are commonly used for fish smoking in the area.

Large quantities, about 500 kg each, of the four fuel wood types were collected simultaneously from three locations in each of the five communities in the Sene District. The communities were Deifour Battor (DB), Kojokrom (KJ), Kajaji (KA), Chaboba (CH), and Nketia Akuraa (NA). The fuel wood types collected were *T. avicennoides* (TA), *A. leiocarpus* (AL), *C. ghasalense* (CG), and *P. erinaceus* (PE). In each community, wood of all species were collected from three locations (1-3). Four fuel wood batches, one from each tree species, and a fifth batch comprising a combination of *T. avicennoides*, *A. leiocarpus*, and *C. ghasalense* were used for smoking the fish (Table 1). The combination of fuel wood was included to mimic the practice of the traditional fish smokers.

The freshwater fish Bagrid, *Chrysichthys auratus*, was used for the study. It is the most commonly smoked fish in Deifour Battor. The fish was purchased in a prime fresh state direct from a local fisherman. The sizes of each batch of the fresh *C. auratus* were assessed by measuring the total length (head to tail) of 30 randomly selected fish with a tape. The weights of 10-15 pieces of the fish, depending on their sizes, were also measured with the Salter Model 235 6S (Made in England) weighing scale. Single-unit Chorkor Smokers were constructed and 15 such Smokers were used at any one time.

TABLE 1

Fuel Wood Types Used to Smoke the Fish

T. avicennoides *(TA) Lot 1*	A. leiocarpus *(AL) Lot 2*	C. ghasalense *(CG) Lot 3*	P. erinaceus *(PE) Lot 4*	*Mixed types (TA, AL, CG) Lot 5*
TA/DB1	AL/DB1	CG/DB1	PE/DB1	TA/AL/CG/DB1
TA/DB2	AL/DB2	CG/DB2	PE/DB2	TA/AL/CG/DB2
TA/DB3	AL/DB3	CG/DB3	PE/DB3	TA/AL/CG/DB3
TA/KJ1	AL/KJ1	CG/KJ1	PE/KJ1	TA/AL/CG/KJ1
TA/KJ2	AL/KJ2	CG/KJ2	PE/KJ2	TA/AL/CG/KJ2
TA/KJ3	AL/KJ3	CG/KJ3	PE/KJ3	TA/AL/CG/KJ3
TA/KA1	AL/KA1	CG/KA1	PE/KA1	TA/AL/CG/KA1
TA/KA2	AL/KA2	CG/KA2	PE/KA2	TA/AL/CG/KA2
TA/KA3	AL/KA3	CG/KA3	PE/KA3	TA/AL/CG/KA3
TA/CH1	AL/CH1	CG/CH1	PE/CH1	TA/AL/CG/CH1
TA/CH2	AL/CH2	CG/CH2	PE/CH2	TA/AL/CG/CH2
TA/CH3	AL/CH3	CG/CH3	PE/CH3	TA/AL/CG/CH3
TA/NA1	AL/NA1	CG/NA1	PE/NA1	TA/AL/CG/NA1
TA/NA2	AL/NA2	CG/NA2	PE/NA2	TA/AL/CG/NA2
TA/NA3	AL/NA3	CG/NA3	PE/NA3	TA/AL/CG/NA3

Fish smoking

The traditional fish-smoking procedure was used. The fish were smoked whole and unwashed. Each fish was arched and the caudal fin was forced through the mouth *via* the operculum. Between 10 and 15 fishes weighing 1.3 to 1.9 kg, depending on their sizes, were arranged on a smoking tray and placed on a Chorkor Smoker. The fishes were smoke-dried, starting with a smouldering fire at 60-80 °C for about 120 min to enable the fish to be partially dry and allow gradual smoking. The smoking continued at a relatively higher temperature, using less smoke during the second phase. The fire was carefully controlled to maintain a range of 80-100 °C for about 4 h in order to cook the fish and avoid burning. At this stage the ovens were covered with sheets of plywood. To ensure that the products were evenly cured, the fish were inspected, turned, and rearranged on the trays every hour. The smoking continued at reduced heat of 40-45 °C for a further 6 h. The smoking period lasted 10-15 h. Heat intensity was regulated by adding or removing firewood accordingly, and oven temperature measured with a KM 1242 Kane-May Limited Temperature Recorder. The smoked products were cooled, labelled, and their weights recorded. They were then packed and transported to the laboratory, and kept frozen for chemical and microbiological analyses.

Evaluation of smoked fish samples

Chemical and microbiological analyses were done on milled smoked fish from each of the five Lots (Table 1).

Proximate analysis of smoked fish

Moisture, protein, fat, ash, calcium, and iron contents were determined according to the Standard Methods of AOAC (1990).

Microbiological quality assessment of smoked fish

Microbiological analysis was carried out on both fresh and smoked fish samples. Five grams

of whole-milled fish samples was homogenized in 45-ml quarter-strength Ringers solution. Total counts were determined according to Harrigan & McCance (1966). Mould and yeast count was determined by the Pour Plate Technique using Malt Extract Agar (Anon, 1987). Enterobacteriaceae (coliforms) were counted following the procedure given by the Nordic Committee of Food Analysis (Anon, 1992). Pathogenic bacteria, *Salmonella* sp. and *Staphylococcus aureus*, were determined by the methods of the Nordic Committee of Food Analysis (Anon, 1991, 1992).

Hydrogen ion concentration (pH)

Hydrogen ion concentration of the samples were determined with a Laboratory *p*H Meter M92 (Danish-made).

Results and discussion

Table 2 shows the length measurements of randomly selected samples of the fish used in the study.

TABLE 2

Length Measurements (Head to Tail) of Fresh C. auratus

Sample	*Length (cm)*
1	22.5 - 29.0 ± 1.88
2	23.0 - 30.0 ± 2.16
3	22.0 - 30.0 ± 1.99
4	22.0 - 30.0 ± 1.69
5	22.5 - 29.0 ± 1.81

Proximate quality characteristic of smoked Chrysichthys auratus

Smoked *Chrysichthys auratus* were high in protein (46-57 %), fat (15-33 %), and ash (12-17 %) contents. As fresh fish has a moisture content ranging from 70 to 80 per cent, smoking drastically reduced the moisture level to about 9-13 per cent (Table 3).

Proximate analysis confirmed that protein, fat, and ash are the major components (Table 3). The moisture contents (9-13 %) were low enough to present little deterioration problems if storage conditions were properly controlled. The drying effects of smoking lower the water activity and will contribute to the stability of the smoked product. Okoso-Amaa *et al.* (1978) indicated that shelf life of smoked *Sardinella* spp. varied according to the moisture content. Plahar *et al.* (1996) later recommended an initial smoked fish moisture content below 13 per cent before storage. They reported that this condition would also not favour the development of aflatoxin-producing moulds. However, at moisture levels of 15 per cent and above, a great deal of proteolytic and lipolytic deterioration as well as microbial proliferation are favoured (Kaneko, 1976). The fat levels (15 - 33 %) were high and may cause rancidity problems within a short period of storage (Plahar, Pace & Lu, 1991).

Microbiological quality of fresh and smoked Chrysichthys auratus

Table 4 shows the results of microbiological analysis of fresh and smoked *Chrysichthys*

TABLE 3

Proximate Composition of Smoked Chrysichthys auratus *According to Fuel Wood Used*

Sample	T. avicennoides *(TA) Lot 1*	A. leiocarpus *(AL) Lot 2*	C. ghasalense *(CG) Lot 3*	P. erinaceus *(PE) Lot 4*	*TA/AL/CG Lot 5*
Moisture (%)	11.3	9.7	12.8	10.4	8.8
Protein (%)	50.8	51.0	46.1	56.6	48.7
Fat (%)	26.1	22.6	17.9	14.8	33.4
Ash (%)	13.9	17.1	13.1	16.0	12.2
Calcium (mg/100 g)	5293.5	5909.5	5752.0	4020.5	4033.5
Iron (g/100 g)	14.5	9.4	4.3	10.0	10.6

TABLE 4

Microbiological Quality of Fresh and Smoked Chrysichthys auratus

Sample	pH	*Aerobic mesophile count/g*	*Mould & Yeast*	*Culture (microflora)*	Coliforms *0.1g*	*Faecal* Coli	Staphylococci; Salmonella; Vibrio
Fresh fish	6.3	1.3×10^5	-	Gm +ve Cocci & rods Gm +ve rods	F	F	NF
Lot 1	6.3	2.2×10^3	3.2×10^2	Gm +ve Cocci & rods *Rhizopus & Aspergillus* spp.	NF	NF	NF
Lot 2	6.2	6.0×10^1	<10	Gm +ve Cocci & rods	NF	NF	NF
Lot 3	6.6	7.3×10^3	1.0×10^1	Gm +ve Cocci & *Rhizopus*	NF	NF	NF
Lot 4	6.4	5.0×10^1	1.0×10^1	Gm +ve Cocci	NF	NF	NF
Lot 5	6.4	1.3×10^2	<10	Gm +ve Cocci & rods	NF	NF	NF

Lot 1 = Fish smoked using *T avicennoides*; Lot 2 = Using *A. leiocarpus*; Lot 3 = Using *C. ghasalense*; Lot 4 = *P. erinaceus*; Lot 5 = Using combination of TA, AL, CG. F = Found NF = Not found

auratus samples. The results indicate that the initial microbial types and viable numbers on the fresh fish decreased during smoking but were not completely eliminated. Smoking eliminated *Coliforms* and faecal *coli* found on the fresh fish samples. Pathogenic bacteria *Staphylococcus* and *Salmonella* were absent in all the smoked samples analysed. The absence of *Coliforms* and faecal *coli* in the smoked samples indicate the absence of human and animal sources of contamination during processing. The main microorganisms isolated from the smoked samples were *Bacillus* and *Micrococci* spp. The mould isolates were *Rhizopus* and *Aspergillus* spp. which are common fungi. These results suggest that the microbiological quality of the smoked fish may be considered acceptable.

Conclusion

The results confirm that the smoked *C. auratus* samples are a good source of protein, fat, calcium, and iron. Smoking drastically reduces the moisture content of the smoked fish to levels that fall within the range that will contribute to good storage, and not favour the development of mycotoxin-producing moulds. The high fat levels may cause rancidity problems within a short period of storage.

The smoking process was effective in reducing the microbial load on the smoked fish. *Coliforms* and *faecal coli* found on the raw fish sample were eliminated from the smoked fish. Pathogenic bacteria (*Staphylococcus* and *Salmonella* spp.) were not found on any of the smoked samples. The microbiological quality of the smoked fish was therefore improved.

The fuel wood species generally preferred for fish smoking in the Sene District were *T. avicennoides, A. leiocarpus,* and *C. ghasalense.* These imparted the much liked yellowish-brown colour to the smoked fish, whilst *P. erinaceus* imparted black colour to the smoked fish and was therefore disliked for fish smoking.

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