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Effect of Local Processing Methods (Cooking, Frying and Smoking) on Three Fish Species from Ghana: Part I. Proximate Composition, Fatty Acids, Minerals, Trace Elements and Vitamins

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ABSTRACT

*The effect of processing methods (cooking, frying and smoking) on the chemical composition of two marine fish (*Sardinella *sp., *Dentex *sp.) and a freshwater fish (*Tilapia *sp.) was studied.*

The proximate compositions of the fish were similar to those of other fish reported in the literature. Processing per se *had no effect on the composition of fish.*

Smoking and cooking did not affect the fatty acid composition of the fish. The palm-kernel oil used in frying masked the fatty acid pattern in the fried fish. Freshwater fish contains high levels of n-6 fatty acids. However, similar amounts were found in the freshwater fish and the marine fish. This is probably due to the freshwater fish feeding on mosquito larvae.

The fish contained appreciable amounts of Na, Ca, P and Mg. Trace elements (Fe, Cu, Zn and As) were also determined.

There was no thiamine in flat sardine and tilapia, probably due to thiaminase activity. The content in Dentex *sp. was low. Vitamins* B_2 *and* B_6 *were very low in all the fish.*

INTRODUCTION

Fish is a major source of food to mankind. It provides a significant amount of the animal protein intake in the diet of a large proportion of people in the

developing countries. In the Ivory Coast, for instance, fish provides about two-thirds of the animal protein in coastal regions, more than half in the forest region and less in the savanna (FAO, 1986).

Furthermore, it provides fatty acids, minerals and vitamins.

Along the west coast of Africa, *Tilapia* sp., *Sardinella* sp. and *Dentex* sp. are among the most popular fish species used as food. Methods of preparation before consumption are different from those of other parts of the world. Fish is cooked for long periods in soups or stews; deep frying is employed and smoking at high temperatures is the rule. There are few data on the nutrient composition of these fish species.

The proximate compositions of the above-mentioned species, both fresh and processed (cooking, smoking and frying), as well as the fatty acid profiles, contents of minerals, trace elements and some water soluble vitamins are discussed in this paper.

MATERIALS AND METHODS

Materials

Three types of fish from Ghana were used, the salt water fish, flat sardine (*Sardinella* sp.) and sea bream (*Dentex* sp.) and the freshwater fish, tilapia (*Tilapia* sp). They were bought fresh, that is when they were caught and brought ashore by the local fishermen. About 1 kg of each type of fish was assigned to each processing method. Frying and smoking were done immediately. The remainder was frozen. The fried, smoked and frozen fish were transported by air to Bergen, Norway, where cooking of the frozen fish and the main analytical work took place.

Preparation of fish for smoking and the smoking process

The treatment before smoking depends on the type and the size of the fish. The size range of the fish was 12–17 cm. The gills, guts and scales of flat sardine were not removed. For sea bream only the scales were removed. The guts and scales were removed for tilapia. The fish were then washed in clean, fresh water and carefully arranged on trays. They were left for about 1 h to dry in the sun before smoking. The Chorkor smoker, an improved traditional oven made of clay and mud, was used for the smoking.

The fish were hot smoked for 2 h at temperatures above 80°C prior to being cooked. Thereafter, they were smoke-dried over moderate heat. For the hot-smoking plenty of hard wood was used. For the smoke-drying a small amount of hard wood and moistened coconut husk were used to produce enough smoke.

Preparation, cooking and frying of fish

The fish were prepared by removing the head, scales and guts. They were washed in freshwater and about 2 g of NaCl added to each 1 kg of fish.

One kilogram each of flat sardine, sea bream and tilapia were separately cooked. The fish with 0·5 litre of cold water were placed in a saucepan, covered with a lid and allowed to cook for 30 min.

The method of deep frying was used to fry the fish. A traditional deep frying pan was used. Three litres of fresh palm-kernel oil were used for each batch of 1 kg. The oil was first heated until a blue haze was emitted. The salted fish from each species were fried for 20 to 30 min.

Preparation of fish samples for analysis

The heads, scales, guts, spine and fin bones of the fish were removed. The fish samples were then homogenised using a kitchen blender. Each sample was spread on disposable aluminium plates, covered with foil and frozen for 2 days. The samples were then freeze-dried, homogenised to a fine powder and stored in tight plastic containers.

Samples used for the determination of the fatty acids and vitamins were frozen wet to avoid oxidation. The samples were stored at $-18°C$.

Methods

Moisture and ash were determined by conventional methods. Protein (N × 6·25) was determined as described by Crooke and Simpson (1971) after digestion in a Tecator block digestor at about 370°C. Fat and fatty acids were determined as described by Losnegard *et al.* (1979) and Lie *et al.* (1987), respectively.

For mineral determination, the samples were digested in $HNO_3/HClO_4$ (9/1) as described by Julshamn *et al.* (1982). All the elements were measured by atomic absorption spectrophotometry (AAS). The elements Ca, Mg, Fe, Cu and Zn were determined by acetylene–air–flame atomic absorption, and Na and K by flame atomic emission (Perkin Elmer Model 3030). Standard curves were used for the determination of the elements in question. Arsenic (As) and P were measured by graphite furnace AAS (Perkin Elmer Model 5000 equipped with deuterium background corrector and a Perkin Elmer HGA-500 graphite furnace) using nickel as matrix modifier as described by Julshamn *et al.* (1990).

Thiamine was determined using *Lactobacillus viridescens* (12706 ATCC) after Diebel *et al.* (1957). The vitamin was extracted with 0·05M H_2SO_4 for 30 min in flowing steam in an autoclave. The extract was incubated with

0·15 M sodium acetate buffer overnight at 37°C. The turbidity of the solutions was measured at 660 nm by a spectrophotometer calibrated against the test organism. A standard curve was plotted and from this the concentrations of the samples were determined.

Riboflavin was determined using *Leuconostoc mesenteroides* (10100 ATCC) after Barton-Wright (1963). It is very sensitive to both visible and ultraviolet light so all the analyses were carried out in subdued light. Measurement of growth was done as described under the thiamine determination.

The estimation of pyridoxine was carried out after a method modified by Atkin *et al.* (1943) using *Saccharomyces carlsbergensis* (9080 ATCC) as the test organism. The analyses were carried out in the dark as pyridoxine is light sensitive. The vitamin was extracted by autoclaving at 120°C for 4 h with 1 M H_2SO_4. The vitamin content was estimated as under thiamine determination.

RESULTS AND DISCUSSION

The proximate composition of the three species of fish (in the fresh and processed forms) is presented in Table 1. The composition data, based on the

TABLE 1
Proximate Composition (g/100 g, dry matter basis)[a]

Samples	*Dry matter*	*Protein*[b]	*Fat*	*Ash*
Flat sardine				
Fresh	24·6 ± 0·4	84·1 ± 0·3	0·7 ± 0·0	13·1 ± 0·0
Cooked	25·2 ± 0·7	82·0 ± 1·1	1·3 ± 0·0	13·9 ± 0·4
Fried	63·6 ± 0·3	56·7 ± 0·1	28·0 ± 0·0	7·7 ± 0·2
Smoked	53·2 ± 0·2	84·7 ± 1·4	3·6 ± 0·0	8·1 ± 0·1
Sea bream				
Fresh	25·7 ± 0·5	79·1 ± 0·7	10·0 ± 0·1	8·6 ± 0·3
Cooked	30·1 ± 1·2	73·1 ± 0·3	13·7 ± 0·1	11·1 ± 0·1
Fried	68·5 ± 0·4	61·8 ± 0·2	27·1 ± 0·3	8·7 ± 0·0
Smoked	77·0 ± 1·0	78·4 ± 0·8	10·7 ± 0·1	8·6 ± 0·1
Tilapia				
Fresh	25·9 ± 0·5	67·7 ± 2·1	16·8 ± 0·4	10·8 ± 0·3
Cooked	27·5 ± 0·1	63·3 ± 1·3	19·9 ± 0·1	11·4 ± 0·5
Fried	57·2 ± 0·3	58·2 ± 0·8	31·0 ± 0·1	8·9 ± 0·1
Smoked	79·3 ± 1·0	63·7 ± 1·2	22·5 ± 0·6	11·1 ± 0·1

[a] Mean ± difference between duplicates.
[b] N × 6·25.

fresh samples, are similar to those of other marine and freshwater fish. However, the differences found in the three types of fish may be related to such factors as size, ecological, physical and nutritional status of the fish (Love, 1957). Stansby and Olcott (1963) and Burt (1988) further asserted that differences exist between species and within the same species from one individual to the other. Even when samples are taken from the same catch, the composition of fish varies considerably.

The dry matter content increased considerably through frying and smoking (Table 1). The increase in dry matter with frying is mostly due to the absorption of fat by the fish. That of the smoked fish is due to loss of water during processing.

The protein contents of the marine fish are similar to the findings of Opstvedt *et al.* (1970) on fish meals from different species and the freshwater fish to that of Balogun (1988) on freshwater fish species. The protein levels of the fresh samples were fairly stable with cooking and smoking but showed significant reduction on frying. The lower protein content of the fried fish is due to dilution with the oil used in frying.

The lipid content in the fish classify them as low oil–high protein for flat sardine and medium oil–high protein for sea bream and tilapia (Stansby & Olcott, 1963). The fat content increased with processing; the greatest increase was observed in the fried samples.

All samples showed high ash content (Sure & Easterling, 1952; Opstvedt *et al.*, 1970). The higher ash content in the fresh samples of sardine and tilapia than of sea bream is because these species are bony.

Table 2 presents the fatty acid composition of the lipids of the fishes. The results of the analyses of the three types of fish are similar to what Bligh *et al.* (1988) have reported on fish lipids.

In comparing the fresh and the processed samples, the results indicate that cooking and smoking had little or no effect on the fatty acid composition. Myklestad *et al.* (1972) found that intensive heat treatment of herring meal led to stabilization of the lipids as shown by the high iodine value for the various fish meals. Conversely, Balogun (1988) observed that sun-drying of freshwater clupeids had a detrimental effect on the lipid characteristics.

The palm-kernel oil used for frying contains 44%–54% of 12:0 fatty acid and also high quantities of the 14:0 and 18:1 series. These fatty acids masked the fatty acid pattern in the fried samples as judged by the high percentages of unidentified acids. The levels of 14:0 and 18:1 were also higher in the fried fish than in the fresh. In view of the above, the fried fish cannot be a good source of the omega-3 fatty acids which have an important nutritional role in combating coronary heart diseases (Dyerberg & Bang, 1979; Bang *et al.*, 1980) and protection against breast cancer (Kaizer *et al.*, 1989). However, if there is a need to increase the energy density of a diet, then fried fish could

TABLE 2
Fatty Acid Composition of the Lipids (% total lipid)

Fatty acid	*Flat sardine*				*Sea bream*				*Tilapia*			
	Fresh	*Cooked*	*Fried*	*Smoked*	*Fresh*	*Cooked*	*Fried*	*Smoked*	*Fresh*	*Cooked*	*Fried*	*Smoked*
14:0	2·3	2·1	16·0	9·0	3·0	3·0	14·4	3·7	5·2	5·2	14·2	5·2
16:0	28·0	24·7	10·4	29·0	25·2	25·2	10·4	22·9	30·2	30·2	13·5	28·9
16:1[a]	4·0	3·6	0·3	6·8	6·8	6·8	0·4	4·7	15·1	15·1	2·2	16·1
18:0	7·4	7·5	3·3	6·6	10·0	10·0	3·3	9·2	5·6	5·6	3·5	5·5
18:1[a]	9·5	9·4	17·2	8·7	13·4	13·4	15·7	13·6	16·5	16·5	16·0	17·4
18:2ω6	1·4	1·4	2·7	1·7	1·0	1·0	2·3	1·1	2·6	2·6	2·5	2·9
18:3ω3	0·5	0·4	0·1	0·3	0·3	0·3	—	0·3	0·3	0·3	0·7	4·2
18:4ω3	0·2	—	—	0·7	0·1	0·3	—	0·2	2·3	2·3	—	0·4
20:1	1·5	0·4	0·1	0·5	2·0	2·0	0·2	1·8	4·7	4·7	0·2	0·5
20:4ω6	3·1	3·3	0·2	2·3	2·1	2·1	0·3	2·4	1·3	1·3	0·4	1·2
20:4ω3	—	—	—	0·2	0·4	0·4	—	0·2	0·6	0·6	—	0·6
20:5ω3	3·5	4·0	0·4	8·6	6·2	6·2	0·7	5·7	1·0	1·0	0·4	1·8
22:1*	0·5	—	—	0·3	—	—	—	—	—	—	—	—
22:5ω3	0·5	0·7	0·1	1·3	2·8	2·8	0·3	2·6	3·2	3·2	0·5	2·8
22:6ω3	28·2	34·2	2·2	16·0	19·0	19·0	3·7	17·8	3·4	3·4	0·7	3·4
24:1	—	0·3	—	0·2	—	—	—	0·3	—	—	—	—
Others	9·4	8·0	47·0	7·8	7·7	7·6	48·2	13·5	8·1	8·1	45·2	9·1
Sum sat.[b]	37·7	34·3	29·7	44·6	38·2	38·2	28·1	35·8	40·9	40·9	31·2	39·6
Sum mono.[c]	15·5	13·7	17·6	16·5	22·2	22·1	16·4	20·4	36·2	36·2	18·5	34·0
Sum poly.[d]	37·4	44·4	5·7	31·1	31·9	32·1	7·3	30·3	14·7	14·7	5·2	17·3

[a] Sum of isomers.
[b] Sum of saturated fatty acid.
[c] Sum of monounsaturated fatty acid.
[d] Sum of polyunsaturated fatty acid.

make an important impact. The high value of unidentified acid obtained for smoked sea bream remains obscure.

From the above it may be concluded that processing *per se* does not affect the fatty acid composition. What actually affects the acids are external factors such as light, UV rays and available oxygen (Khayat & Schwall, 1983).

Comparing the marine fish with the freshwater fish, the distinctive point in the freshwater fish fats is the small proportion of unsaturated fatty acids (C_{20} and C_{22}). In the C_{20} and C_{22} groups, the average unsaturation varies considerably, being greater in the fats of freshwater fish from temperate waters than from the tropics. In some of the latter, C_{22} acids are absent or only present to the extent of 1 to 2% (Hilditch & Williams, 1964). The freshwater fish also showed increased proportions of 16:0 and 18:1 but reduced amounts of 18:0. Furthermore, the fresh and marine fish had equal amounts of saturated fatty acids but different proportions of the monounsaturated and polyunsaturated, the latter being higher in marine fish species. Normally, one would expect high levels of n-6 acids in freshwater fish. These were, however, about the same as those of fresh marine fish. The differences seen in the fatty acid composition may largely be due to dietary fats. The freshwater fish from Ghana probably feed on mosquito larvae. Feeding experiments have shown that fats become incorporated into the depot fats of the fish. This fact, coupled with corresponding differences in the fats of marine and freshwater plankton, probably explains the two types of fats in marine and freshwater fish (Lovern, 1935, 1938 and 1951).

Table 3 shows the composition of the major and trace elements. The processing methods under consideration generally had little or no effect on the elements. The values for Na and K were highest for flat sardine as compared to the other two fish species. The higher Na values seen in the cooked and fried samples, relative to the fresh, are due to the addition of salt (NaCl) during processing. The marine fish showed higher Na values than the freshwater types. The higher values in marine fish may be due to the different content of sea water.

The values for calcium (Ca), phosphorus (P) and magnesium (Mg) varied among the species. The highest concentrations were observed in tilapia and flat sardine, which have high contents of bone.

Flat sardine and tilapia had higher values of Fe than sea bream. This indicates higher levels in products high in bones (Julshamn *et al.*, 1978). The highest concentration of iron was found in sardine. Dark-coloured tissue contains more iron than light-coloured tissue (Parks & Rose, 1933). The Zn content, found in sea bream, was similar to the results reported for fish muscle, whereas the Zn values of the other two species are similar to whole

TABLE 3
Composition of Elements in Three Fish Species (dry weight)[a]

Sample	*Major elements (g/kg)*					*Trace elements (mg/kg)*			
	Na	*K*	*Mg*	*Ca*	*P*	*Fe*	*Cu*	*Zn*	*As*
Flat sardine									
Fresh	27·3 ± 0·6	20·3 ± 0·1	1·9 ± 0·1	16·2 ± 1·2	12·2 ± 0·4	74·5 ± 3·6	2·8 ± 1·8	63·7 ± 0·4	10·4 ± 1·2
Cooked	35·7 ± 1·1	20·2 ± 0·8	1·6 ± 0·0	11·2 ± 3·2	16·2 ± 1·9	73·4 ± 2·1	3·7 ± 0·1	69·2 ± 4·6	11·3 ± 1·0
Fried	11·8 ± 0·4	15·1 ± 0·2	1·5 ± 0·2	12·8 ± 3·2	10·4 ± 1·6	67·1 ± 3·1	1·8 ± 0·0	67·1 ± 4·5	7·4 ± 0·8
Smoked	11·7 ± 0·3	17·4 ± 0·5	3·3 ± 0·0	8·1 ± 2·0	8·3 ± 0·9	91·7 ± 1·5	3·7 ± 0·1	49·7 ± 0·9	3·1 ± 0·4
Sea bream									
Fresh	12·5 ± 0·2	19·0 ± 0·2	1·4 ± 0·1	9·7 ± 0·7	10·3 ± 2·3	27·6 ± 0·0	1·9 ± 0·0	23·8 ± 1·9	12·6 ± 1·2
Cooked	27·0 ± 0·2	17·7 ± 0·1	1·4 ± 0·0	8·4 ± 0·0	7·4 ± 0·8	26·0 ± 3·0	2·8 ± 1·8	32·0 ± 5·3	14·4 ± 0·1
Fried	18·0 ± 1·0	15·0 ± 0·7	1·5 ± 0·0	13·3 ± 1·7	13·7 ± 0·0	53·4 ± 3·0	1·9 ± 0·0	30·3 ± 3·7	7·5 ± 1·4
Smoked	3·5 ± 0·4	18·0 ± 0·8	1·6 ± 0·1	20·1 ± 2·9	12·6 ± 2·0	91·2 ± 2·7	1·8 ± 0·0	50·0 ± 4·1	11·1 ± 1·2
Tilapia									
Fresh	10·5 ± 0·9	14·7 ± 1·0	1·7 ± 0·5	24·0 ± 0·6	13·2 ± 0·8	31·9 ± 2·7	1·8 ± 0·0	51·0 ± 1·2	<0·5
Cooked	16·5 ± 0·3	13·4 ± 0·7	1·4 ± 0·1	20·6 ± 0·6	8·0 ± 1·1	38·0 ± 2·4	3·7 ± 0·1	56·4 ± 4·7	<0·5
Fried	14·6 ± 1·1	13·3 ± 0·8	1·2 ± 0·4	18·5 ± 0·1	5·6 ± 2·0	44·0 ± 3·3	1·8 ± 0·0	46·2 ± 4·8	<0·5
Smoked	2·8 ± 0·4	12·6 ± 0·0	1·5 ± 0·0	33·1 ± 2·6	16·9 ± 3·6	98·6 ± 1·1	3·7 ± 0·1	55·9 ± 3·6	<0·5

[a] Mean ± difference of duplicates.

fish (Julshamn *et al.*, 1978). This could be due to the bony nature of sardine and tilapia. All the species had about the same quantities of Cu. The ranges of values are similar to the findings of Julshamn *et al.* (1978).

Arsenic has not been shown to be essential but it is a well-known toxic element. The freshwater fish (tilapia) showed a low content (less than 0·5 mg/kg) but levels of 10 mg/kg and 13 mg/kg were seen in the marine fish, sea bream and flat sardine, respectively. This difference in As between the freshwater and the marine fish is well known and it is due to the fact that marine organisms accumulate substantially higher amounts of arsenobetaine than freshwater organisms (Norin & Vahter, 1984). Arsenic content of marine fish products, ranging from 0·2 to 19 mg/kg, have been reported by Egaas and Brækkan (1977).

Table 4 shows the results for thiamine, riboflavin and pyridoxine in the fish samples. There was no thiamine in flat sardine and fresh and cooked tilapia. This might be due to the presence of thiaminase, an enzyme which destroys thiamine by splitting the methylene bridge. Trace amounts were observed in fried and smoked tilapia. Degradation leads to the formation of biologically inactive pyrimidine and thiazole. The latter is known to confer flavour on food which can be sweet, meaty or pungent (Wilson, 1975).

Thiaminase occurs in many species of fish and shellfish. In general, the enzyme seems to be confined to certain types of freshwater fish. However, a

TABLE 4
Composition of Vitamins (mg/kg, dry weight)[a]

Sample	*Thiamin*	*Riboflavin*	*Pyridoxine*
Flat sardine			
Fresh	nf	1·3 ± 0·2	5·3 ± 0·1
Cooked	hf	1·0 ± 0·1	4·3 ± 0·2
Fried	nf	1·5 ± 0·5	4·8 ± 0·1
Smoked	nf	1·3 ± 0·2	6·5 ± 0·0
Sea bream			
Fresh	0·2 ± 0·0	0·5 ± 0·1	5·0 ± 0·5
Cooked	0·6 ± 0·1	0·5 ± 0·3	2·4 ± 0·1
Fried	0·2 ± 0·0	1·3 ± 0·1	3·6 ± 0·0
Smoked	0·2 ± 0·0	0·9 ± 0·1	3·6 ± 0·1
Tilapia			
Fresh	nf	1·3 ± 0·0	2·0 ± 0·3
Cooked	nf	1·5 ± 0·1	1·1 ± 0·1
Fried	0·1 ± 0·0	4·3 ± 0·1	1·0 ± 0·3
Smoked	0·1 ± 0·0	3·3 ± 0·1	1·2 ± 0·3

[a] Mean ± difference between two set up.

number of salt water fish, particularly, herring, also contain the antivitamin factor (Borgstrom, 1968). The enzymes are either an intrinsic part of the flesh or on the surface. Enzymatic destruction can be prevented by heat treatment. Kundig and Somogyi (1967), however, found a thermostable antithiamine factor in carp viscera. Aitken and Connell (1979) asserted that thiamine is destroyed to varying degrees depending upon the species and the conditions of heat treatment. There is loss on smoking and complete destruction has been reported by Cutting (1962) during the salting and drying of certain tropical products. In contrast to this, the amount (0·2 mg/kg) in sea bream was relatively stable with processing. Ang *et al.* (1975) observed an average retention of thiamine in fish portions subjected to various heat treatments to range from 77% to 104% relative to the frozen fish.

In 1957, Adrian reported that riboflavin is the only B-vitamin which is not essentially retained during the preparations of 14 salted and dried fish products in Angola. Nevertheless, significant amounts were found (Koyama, 1960) in the dark muscle of dried-smoked bonito. The present study indicated that riboflavin is relatively stable in the processed fish as compared to the fresh.

The processing methods under consideration affected the pyridoxine content of the fish in the negative sense. Losses up to 30% have been reported in freeze-dried fish (Shroeder, 1971).

For the microbiological assay of B_6, the test organisms vary in their response to the different forms of the vitamin (pyridoxine, pyridoxal and pyridoxamine). This might have influenced the results.

Fish contains small amounts of nearly all the vitamins. The contributions of fish to the vitamins are of significance when large quantities are consumed. Furthermore, unless a diet is largely based on fish, the stability of vitamins during processing will be of only minor importance. The effects of processing must be compared with raw fish of the same batch to draw meaningful conclusions. Comparisons with tabulated values must be treated with caution (Cutting, 1962).

Drying procedures may or may not involve heat. Smoking and frying usually does. In the case of smoking, losses may result from interaction with smoke components. It is noteworthy that any changes in nutritional value during dehydration are likely to occur when similar amounts of dehydration occur during smoke-drying.

The fat-soluble vitamins are generally more stable than the water-soluble ones. They are, however, prone to degradation at high temperatures and in the presence of oxygen (Priestley, 1979). Products of lipid oxidation can interact with the fat-soluble vitamins (Daun, 1975), and measures used to protect lipids will also improve the retention of these vitamins.

The results and the evidence cited show that the different vitamins in fish are destroyed to varying extents as a result of processing, external factors such as light, oxygen and other intrinsic factors such as enzymes. The proportion of fish in the diet will determine the importance of the contribution made by fish to the total intake of any particular nutrient.

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