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Risks associated with the consumption of fish grilled on charcoal in the commune of Man (Côte d'Ivoire)

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Abstract

Braised fish is a cooking method very popular among the people of Man. The survey conducted among the vendors of the large night markets of the city of Man (Côte d'Ivoire) identified three types of fish mainly used in this type of cooking. Among these three types of fish, *Cyprinus carpio* is the most sold. Thin-layer chromatography analysis of braised fish purchased at night markets revealed the presence of two polycyclic aromatic hydrocarbons: benzo(a)anthracene and another unidentified compound. The dosage of heavy metals also showed the presence of certain heavy metals in the muscles of purchased braised fish. The heavy metal levels vary depending on the type of fish. In *Cyprinus carpio*, the metals found are copper, nickel, zinc and manganese with respective contents of 0.06% ; 0.01% ; 0.13% and 0.48%). In *Trachurus trachurus*, the metals found are chromium, zinc, nickel, manganese, copper, cadmium with respective contents of 0.09% ; 0.26% ; 0.1% ; 0.1% ; 0.16% and 0.06%. For *Scomber japonicus*, the same metals are found as in *Trachurus trachurus* but the contents differ. Regular consumption of braised fish sold in the night markets of the city of Man would present health risks for consumers.

Keywords: Braised fish; Heavy metals; Polycyclic aromatic hydrocarbons; *Cyprinus carpio*; *Trachurus trachurus*; *Scomber japonicus*

1. Introduction

Fish and its derivatives play an important role in the diets of populations worldwide [1]. They are the primary source of animal protein in Côte d'Ivoire. Per capita fish consumption in Côte d'Ivoire has been estimated at 24.9 kg per year since 2020 [2].

Fish are highly perishable in their fresh state, and due to insufficient preservation equipment, among other factors, the fish industry, particularly artisanal processing, has grown considerably [3]. In Côte d'Ivoire, artisanal fish processing methods are varied and diverse. These include smoking, fermentation, and braising. Braising fish is a process that involves cooking the fish with an aromatic garnish and briefly soaking it, while placing it in direct contact with the embers via a grill [4]. Grilled fish are popular with the population during nighttime outings. Unfortunately, the consumption of grilled fish could have repercussions on human health and could even lead to death. On the one hand, the causes of these diseases (cancers, brain diseases, etc.) can be of primary origin, that is, linked to the living environment of the fish before their capture. Indeed, for several thousand years, surface waters have been subject to the growth of certain actions taken by man due to industrial development leading to its pollution [5]. Large-scale agricultural practices using phytosanitary products at the water's edge also have a share of responsibility for this pollution. Pollution leads to the creation of certain toxic compounds in these waters, including heavy metals, which are ingested by fish during their feeding [6]. These metals accumulate in fish over time and become toxic to humans at a threshold value that can cause certain serious illnesses in consumers in the long term, such as mental disorders [7]. On

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the other hand, the causes may be of secondary origin. Indeed, dishes cooked in direct contact with wood fire or coal can cause cancer in consumers due to their exposure to a mixture of Polycyclic Aromatic Hydrocarbons (PAHs), some of which have been shown to be carcinogenic [8]. PAHs are a particular class of organic compounds and probably the most studied due to their carcinogenic and mutagenic nature [9]. PAHs are generated during pyrolysis or incomplete combustion of organic matter [10]. They are also widespread in the environment and therefore enter the food chain, particularly through air, water and soil. PAHs and heavy metals can also be present in raw materials as a result of environmental and human contamination [11]. People generally suffering from cancer worldwide and particularly in Côte d'Ivoire have been exposed to a mixture of Polycyclic Aromatic Hydrocarbons regardless of the route of exposure (oral, pulmonary and cutaneous) [8]. For the general population, the main source of exposure to PAHs and heavy metals is food [12]. The population of Man is not on the margins of these scourges linked to the consumption of grilled fish. Because this meal is very appreciated by this population. In order to prevent certain risks linked to cancers and brain diseases that this study was conducted. The main objective of this study is to assess the dangers linked to the consumption of fish grilled on charcoal in the city of Man.

2. Material and methods

2.1. Materials

2.1.1. Biological Materials

This study was conducted on fish. Three types of fish were used due to their availability and abundance in the night markets of Man City : *Trachurus trachurus* (Figure 1a), *Cyprinus carpio* (Figure 1b), and *Scomber japonicus*.

Figure 1 Braised *Trachurus trachurus* (a) and *Cyprinus carpio* (b)

2.2. Methods

A survey form was designed for this study. The survey was conducted at the night markets in the city of Man, the most well-known of which are the “Doyaguiné night market”, the “Lycée Club night market”, and the “Domoraud night market “(Domoraud crossroads). The objective of this survey was to identify the most popular fish species and the types of wood used in sawmills for charcoal production.

2.2.1. Sampling

The fish used for this study were purchased at the three most well-known night markets in Man City. Nine samples were collected for each type of fish. A total of 27 randomly selected grilled fish were purchased and transported to the laboratory for analysis (Table 1). The fish purchased at night were wrapped in aluminum foil and frozen overnight before being transported to the laboratory in the morning for analysis. The fish were transported in a cooler. This survey was conducted with 50 of the most well-known vendors frequented by customers.

Table 1 Fish collected for handling

Type of fish collected	Number collected	Total
Cyprinus carpio	9	27
Trachurus trachurus	9	
Scomber japonicus	9	

2.2.2. Analytical Methods for Purchased Braised Fish

Qualitative Determination of polycyclic aromatic hydrocarbons (PAHs) by thin layer chromatography (TLC)

PAHs Extraction

A quantity of 100 g of braised fish from each species was digested in 300 mL of a 10% sodium hydroxide solution (v/v: 9/1) of methanol/water. Refluxing was carried out for 2 hours. The reaction mixture was then rapidly poured into a beaker containing 200 mL of saturated sodium chloride solution, while maintaining vigorous stirring. After vacuum filtration of the mixture, the filtrate was collected for liquid-liquid extraction with petroleum ether, followed by liquid-liquid extraction with dimethyl sulfoxide. The petroleum ether phase was finally used for PAH identification tests by TLC.

TLC Identification of PAHs

TLCs were performed on commercial plates (20x20 cm) pre-coated with silica gel on aluminum oxide layers with a fluorescence indicator. The plates were dried at 100°C for 1 hour. Several mobile phases were used: toluene/hexane (6/6: v/v), toluene/dichloromethane (6/6: v/v), and dichloromethane (100). Chromatograms were observed under UV/254 nm and UV/365 nm. Compound assignment was based on the coloration of the fluorescent spots [13] (Loncar et al., 2005). Table 2 presents the PAH standards used.

Table 2 TLC assignment of PAHs from spot stainings under UV/254 nm and UV/365 nm using PAH standards

Compounds	**Spot color**	
	254 nm	365 nm
Benzo(b)Fluoranthene	Blue	Yellow
Benzo(a)Pyrene	Purple	Pink purple
Benzo(a)Anthracene	Blue	Light blue
Anthracene	Blue	Pink
Phenanthrene	Black purple	Pink purple

Source : (Loncar *et al.*, 2005)

2.2.3. Determination of heavy metals

Metals were determined using MESA-50 X-ray fluorescence spectrometry. This technique analyzes the chemical elements that make up a sample. It can be used for a wide variety of materials: minerals, ceramics, etc., in solid or liquid form. It allows the analysis of all chemical elements with an atomic number greater than 12. A 10 g quantity of braised fish muscle was weighed on a calibrated VWR balance. The determination was performed using X-ray fluorescence spectrometry. Zinc (Zn), cadmium (Cd), chromium (Cr), copper (Cu), and manganese (Mn) were analyzed by the spectrometer.

2.3. Statistical Analysis

The results were analyzed using XL-STAT 7.5.3 software. Means were compared using Duncan's test at the 5% level.

3. Results

3.1. Survey

3.1.1. Fish Used for Braising

The results for fish commonly consumed in Man are presented in Figure 2. The survey identified the fish generally used and sold in the night markets of the city of Man: *Cyprinus carpio*, *Scomber japonicus*, and *Trachurus trachurus*. These three types of fish account for 90% of imported products. Among these, carp fish is the most sold, with a percentage of 44%. Generally, more women sellers of braised fish are found in the “Doyaguiné market” than in other markets. A total of 50 women sellers were identified in the three markets. Of the 50 women sellers, 44% sell *Cyprinus carpio*, 32% sell *Trachurus trachurus*, and 24% sell *Scomber japonicus* (Figure 2).

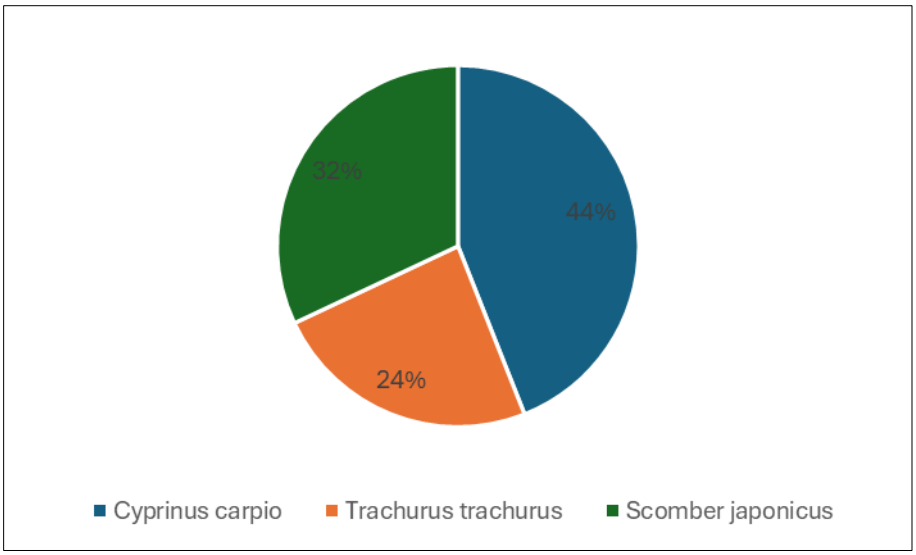

Figure 2 Percentage of female vendors by type of fish

3.1.2. Ingredients and equipment for braising fish

Figure 3 shows that charcoal (98%) is the main material used for braising fish in the night markets of Man City. This charcoal generally comes from sawmills (Figure 4). The woods used to make this charcoal come in several varieties, including redwood and whitewood. Most of these woods are known by their vernacular names, including "Idigbo, Bali, Lidia, Fraké, Afara, Fromager, Kambala, Flamiré, etc." It is important to remember that it is the combination of these surviving woods that is used to make charcoal.

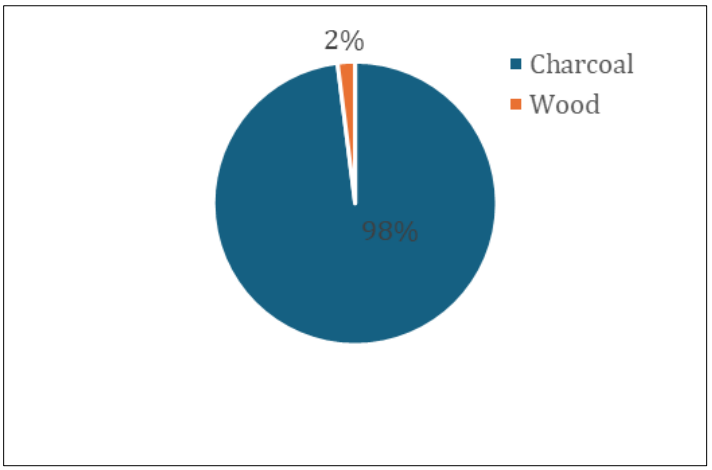

Figure 3 Equipment used for braising fish

Figure 4 Wood residues from the « Mindéba » neighborhood sawmill

Pickle Preparation

The pickle is a purely homogeneous mixture consisting of oil, seasoning cubes, tomato paste, salt, Maggi flavoring for some, chili pepper, Maggi Bourgnon for some, adja and water (Table 3).

Table 3 Main ingredients of the pickle

	Constituent elements
Pickle	Oil, seasoning cube, tomato paste, chili pepper and flavorings, water

3.2. Qualitative Analysis of PAHs

The results of the qualitative determination are presented in Figure 5. In this study, thin-layer chromatography was used to identify and determine selected PAHs in grilled fish sold at the large night markets in the city of Man. The thin-layer chromatography method revealed the presence of benzo(a)anthracene molecules, represented by light blue, and unidentified PAHs, represented by blue.

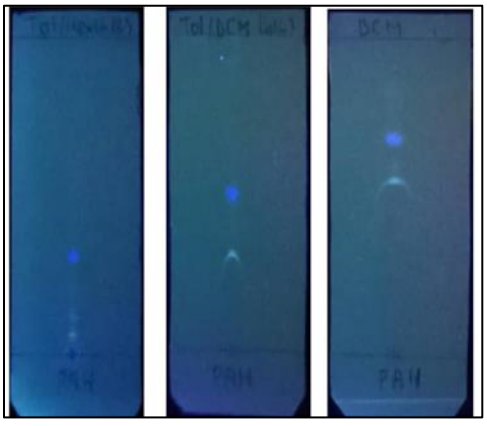

Figure 5 Chromatography plates viewed at 365 nm

3.3. Heavy Metals

X-ray fluorescence spectrometry was used to measure heavy metals in grilled fish purchased at the night markets in the city of Man (Table 4). For the three types of fish, heavy metal levels differed between fish species. The muscles of the fish species Cyprinus carpio sampled contained low levels of manganese (0.48±0.01%) and zinc (0.13±0.2%). They also contained traces of nickel (0.06±0.01%) and copper (0.01±0.1%).

The muscles of the fish species Trachurus trachurus contained the following heavy metals: chromium, zinc, nickel, manganese, copper, and cadmium. The muscles of this species Trachurus trachurus collected contain low levels of zinc (0.26±0.01%), copper (0.16±0.01%), nickel (0.1±0.01%) and manganese (0.1±0.01%). They also contain traces of chromium (0.04±0.0%) and cadmium (0.03±0.0%).

The muscles of the species Scomber japonicus contain the same heavy metals as the fish Trachurus trachurus, but the levels differ. These metals are chromium, zinc, nickel, manganese, copper, and cadmium in respective proportions (0.03±0.0%; 0.62±0.02%; 0.05±0.0%; 0.05±0.0%; 0.26±0.03%; 0.04±0.0%). The muscles of the species Scomber japonicus are loaded with zinc with a concentration of 0.62±0.02% and copper (0.26±0.03%). They also contain traces of chromium, nickel, manganese, and cadmium.

Table 4 Heavy metal content of purchased fish muscles

Fish	Nickel (%)	Manganese (%)	Copper (%)	Zinc (%)	Chromium (%)	Cadmium (%)
Cyprinus carpio	0.06±0.01^{a}	0.48±0.01^{b}	0.01±0.1^{c}	0.13±0.2^{d}	X	X
Trachurus trachurus	0.1± 0.01^{e}	0.1±0.01^{e}	0.16±0.01^{e}	0.26±0.01^{f}	0.04±0.0^{g}	0.03 ±0.0^{g}
Scomber japonicus	0.05±0.0^{h}	0.05±0.0^{h}	0.26 ±0.03^{f}	0.62±0.02^{i}	0.03±0.0^{h}	0.04±0.0^{h}

Values in the same row followed by different letters show significant differences ($p < 0.05$). Each value is the average of the results obtained over 3 determinations ± standard deviation of this average

4. Discussion

The survey conducted among female vendors of grilled fish in Man's night markets identified *Cyprinus carpio*, *Scomber japonicus*, and *Trachurus trachurus* as the fish commonly sold in Man's night markets. It is important to remember that there is no predefined vendor of *Scomber japonicus* or *Trachurus trachurus*. The same people who sell *Scomber japonicus* also sell *Trachurus trachurus*. The vendor's choice of fish depends heavily on the availability and price of fish on the market. *Cyprinus carpio*, which is the most sold in these markets, is the most appreciated by consumers despite its high cost. In reality, consumers of this fish are more or less middle-class citizens. The results of this study differ from those found by Dioné [14]. According to this author, braised fish belong to the large Clupeidae family. These are sardinellas, including *Sardinella aurita* and *Sardinella eba*, and in rare cases, the sardinella (*Ethmalosa fimbriata*).

This fish selling activity is particularly reserved for women; they are the main players in the sale of grilled fish in the city of Man (Côte d'Ivoire). This survey also revealed that female sellers of grilled fish are dispersed, and the number of female sellers is very low compared to other major cities in Côte d'Ivoire.

The women sellers generally use charcoal for grilling fish. The charcoal used by the sellers is a mixture of several wood species. It is produced in local sawmills in the city of Man. Indeed, sawmill residues are transformed into charcoal, which is generally well-priced. For reasons of economy, these sellers prefer this quality of charcoal made from a mixture of woods.

Regarding the qualitative determination of PAHs, the muscles of fish species sold in the city of Man contain certain PAH molecules including Benzo(a)anthracene and a second unidentified one. However, Benzo(a)anthracene (BaA) is one of the 16 priority PAHs considered carcinogenic by US-EPA and therefore capable of causing health problems in humans (Aké-Assi et al., 2010). It is a very toxic compound even at low doses and with chronic effects. Its presence in braised fish taken from the night markets of the city of Man presents a danger to the consumer according to Ake-Assi et al. [15] and Boukari [16]. These authors detected the presence of BaA in smoked fish sometimes depending on the species of fish and the type of wood used. The results of this work corroborate the results of Doornaert *et al.* [8] who state that dishes cooked in direct contact with wood or charcoal fire contain PAH molecules.

As for the second blue compound analyzed, it was not identified using the method described by Loncar e*t al*. [13]. It is likely one of the 11 other compounds remaining on the US EPA list not described by Loncar *et al*. [13]. Identifying this unknown compound requires further analysis using appropriate tools. However, whether it is known or not, it is essential to emphasize its harmful nature to consumers.

Regarding heavy metal levels, the results of this study show that braised fish purchased at night markets are contaminated with certain heavy metals (chromium, cadmium, zinc, manganese, and nickel) and could pose health risks to consumers. The heavy metals found in the muscles of the purchased braised fish species are different from those found by Coulibaly *et al*. [17], except for cadmium. These authors detected the presence of arsenic, mercury, lead and cadmium in the muscles of the fish species *Oreochromis niloticus* "Tilapia"caught in all breeding environments and ready for human consumption. The contamination of purchased grilled fish is linked to water pollution, the lifestyle of the fish used and human action. Indeed, certain actions taken by man such as cultural practices using insecticides and herbicides, oil and mining activities as well as industrial activities along the waters have dramatic consequences on them leading to their pollution [5]. The pollution of these waters also affects the inhabitants of these environments such as fish etc. These activities mostly release heavy metals into these waters which are ingested by fish during their feeding [6]. According to the Saikat *et al*. [18], heavy metals present dangers to humans and therefore can cause health problems. Thus, through the consumption of fish, humans can be exposed to these dangerous elements. Our results corroborate those of Monney *et al.* [19] who revealed the presence of metals in the muscles of smoked fish in three species of fish with high consumption in the area of Abidjan, Côte d'Ivoire.

5. Conclusion

Although grilled fish is enjoyed by many people, it poses health risks to consumers. Regular consumption of grilled fish sold at the night markets in the city of Man may pose health risks. In light of these results, a quantitative study of PAHs and metals and their comparison with the standards set by international institutions is necessary.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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