3.4 Comparison of parameters (moisture, fat, BaP) between fresh and smoked fish

Comparison of parameters (moisture, fat, BaP) between fresh and smoked fish is represented in **figure 3**. The two ellipses overlap in an area, which shows the absence of significant difference in the parameters studied between fresh and smoked fish. As to the individual representation of variables **(figure 4)**, the values of moisture and BaP show a significant difference between fresh and smoked fish of at least 5%.

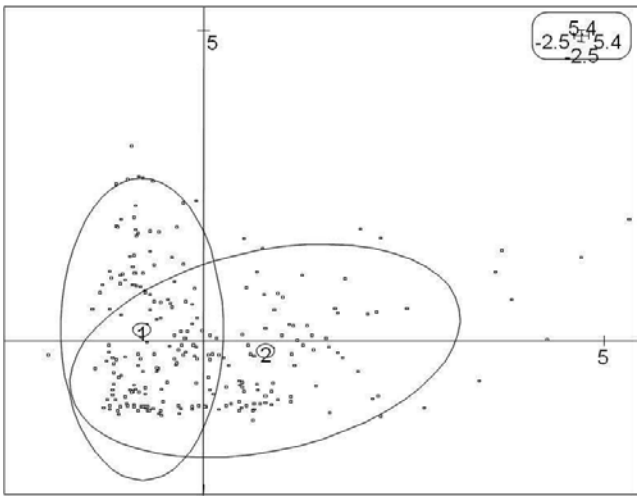

Figure 3: Comparison of parameters studied in fresh and smoked fish (1= fresh fish; 2= smoked fish)

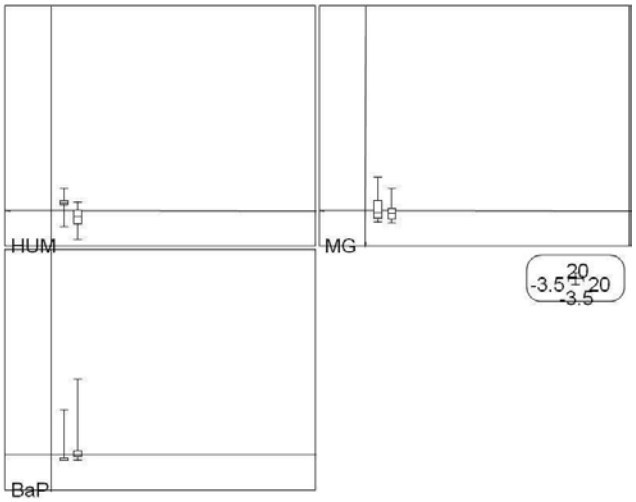

Figure 4: Individual representation of variables in fresh and smoked fish (from left to right: fresh fish; smoked fish)

3.5 Comparison of parameters (moisture, fat, BaP) according to the smoking area

As for the comparison of parameters studied (moisture, fat, BaP) according to the smoking area (**figure 5**), except area n° 4, all the other areas have substantially the same values. Concerning the individual representation of each parameter according to the smoking site (**figure 6**), the values of the parameters studied do not vary with the smoking site.

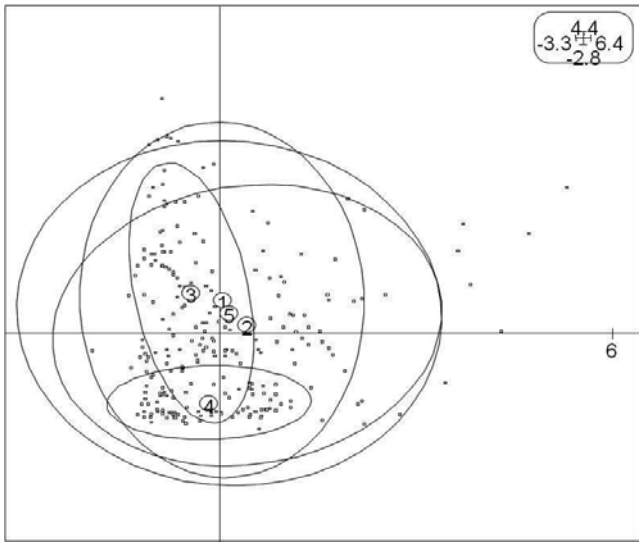

Figure 5: Comparison of parameters studied according to the smoking site (1= Koweït ; 2= Ile Boulay ; 3= Macaci ; 4= Abobo Doumé ; 5= Port-Bouët

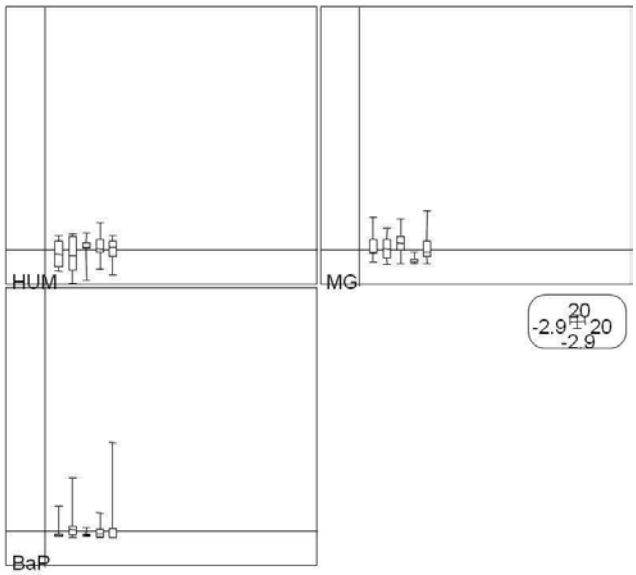

Figure 6: Individual representation of each parameter according to the smoking site (from left to right: Koweït ; Ile Boulay ; Macaci ; Abobo Doumé ; Port-Bouët)

3.6 Influence of moisture and fat on the levels of BaP

The correlation matrix between moisture, fat and BaP (**table 4)** shows that there is significant correlation between moisture and BaP. When the moisture content goes down, the concentrations of BaP in the samples collected increase.

Table 3: Correlation matrix between moisture, fat and BaP in smoked fish

	Moisture	*Fat*	*BaP*
Moisture	1.000000		
Fat	0.026910	1.000000	
BaP	0.341730	0.001020	1.000000

Values in bold show a significant difference (at the 5% level of significance)

3.7 Intakes of Benzo(a)pyrene

The intakes of BaP calculated are presented in **table 5.** These daily intakes were assessed in three categories of individuals:

intake in the occasional consumer (estimated minimum value equal 0.09 ng/kg body weight), intake in the average consumer (estimated average value equal to 9.48 ng/kg body weight) and intake in the large consumer (estimated maximum value equal to 74.5 ng/kg body weight). BaP was found in more than 95 % of the samples tested.

Table 4: Intakes of Benzo(a)pyrene estimated in the Ivorian adult consuming fresh and smoked fish

Fish condition		*Concentration of BaP (µg/kg)*	*Estimated Intake (EI) (ng/kgBW/d)*	*EI/TRV*
Fresh	Min	0.13	0.09	0.018
	Avg	14.65±4.92	10.69±3.59	2.13
	Max	71.26	52.01	10.40
	RV	2	1.46	0.29
Smoked	Min	0.65	0.47	0.09
	Avg	64.97±30.80	47.4±22	9.48
	Max	510.3	372.51	74.50
	RV	5	3.65	0.73

TRV: Toxicity Reference Value = 5 ng/kg body weight/day ; EI: Estimated Intake , Avg: Average; Min : minimal; Max : Maximal

4. Discussion

The results obtained in our study have allowed to show that the methods used to preserve fish through thermal treatment change its chemical composition. In our case, two factors are involved: smoking and flavouring. With the action of flames, the residual water in smoked fish varies between 30 % and 50 %, and the fish is done. The water loss modifies the ideal breeding ground for bacteria responsible for the decrease in the storage time of foods. Traditional smoking of fish is a phenomenon which hinders the growth of bacteria through two actions: dehydration and the antiseptic effect of smoke. The results of this study confirm those of **(12)** and **(13**). The impregnation of smoke in the flesh of the smoked fish gives a characteristic smell to its flesh. But the research of **(14)** shows that the smoke is produced by an indirect combustion process of resinous, wood organic materials with the risk of formation of hydrocarbons as foodstuffs are exposed to products of direct combustion in the presence of open flames. Indeed, the concentration of BaP goes up when moving from fresh fish with an average concentration of 14.65 ±4.92 µg/kg to smoked fish with an average value of 64.97±30.80 µg/kg.

The analysis of the results shows that the smoked fish from the area of Abidjan are contaminated by BaP, a polycyclic aromatic carbon with a proven carcinogenic potential. In **(15**) reported an average level of BaP contamination in smoked fish of about 34.07 µg/kg for a total of 278.22 µg/kg of PAH. That analysis has also revealed that the fresh or frozen raw material was contaminated by BaP before smoking with levels above the regulatory limits. The values found are higher than those of several authors such as **(16)**, **(15)** and **(7)** respectively in fresh fish, smoked fish and smoked meat.

In 2003, AFSSA recommended a guide value about 6 PAHs for 5.5µg/kg of fresh material. In 2012, the research of (**17**) on bush meat highlighted a correlation between BaP and the 6 PAHs (the correlation coefficient was 0.95). The correlation coefficient confirms the role of BaP as marker of the presence of PAHs. The level of BaP contamination in the samples of smoked sardines (64,97 ± 30,80 µg/kg) corresponds to the level of contamination described by AFSSA in 2003 (63 µg/kg) while the BaP values found in the fresh fish used for smoking (14,65±4,92 µg/kg) are at least ten times higher than those described by AFSSA (0.00 – 1.21 µg/kg).

The fat content in the samples of fresh sardines used for smoking is between 5 and 30 %, so the fish are fat as described by **(18**) and the processing technology used at the smoking sites of the area of Abidjan is justified by the necessity of avoiding oxidation reactions. But there is little or no relation between the fat content and the level of BaP contamination in smoked fish.

The analysis of the results has also showed a correlation between the moisture content and the concentration of BaP. The more the product is dehydrated, the more it has undergone the action of heat, either in intensity or in duration, as was confirmed by observations at the smoking sites. The results also highlight a certain specificity of production areas. Indeed, the highest concentrations of BaP are found in the smoked fish taken at the smoking sites of Port-Bouët and Ile Boulay, sites well known as fishing villages (**19**). The concentrations of BaP in the samples of smoked fish are all the higher as the activity takes place in enclaves such as Port-Bouët and Ile Boulay where the unsold smoked fish are reheated several times while stocks last. The major concentrations before smoking are found in decreasing order at Ile Boulay (22.57µg/kg), Abobo Doumé, Koweït, Macaci and Port-Bouët (10.04 µg/kg). The variations of BaP concentrations in fresh fish do demonstrate the contamination of aquatic animals is influenced by their environment, as mentioned by **(18).**

The highest concentrations of BaP were found in the finished products with the lowest moisture content, thus in the products most heated. This result could be explained by the fact that operators use, in general, highy varied fuels, ranging from the simple plant material (branches of rubber tree, of mangrove, cassava peelings, etc.) to the animal material (fish scales). All kinds of wood are appropriate except the rubber tree which causes unpleasant flavour when it is used as a combustion agent for the smoking of foodstuffs (**20**). A comparative study of energy sources has shown that the level of BaP contamination changes with the sources of energy when moving from charcoal to sawdust and branches. So, the regular consumption of foodstuffs with high levels of BaP can be really hazardous for health owing to its prov**e**n carcinogenic potential.

The concentrations of BaP in fresh fish are seven times the regulatory value (Ivorian Ministerial Order No 065 MIPARH 2010, Commission Regulation (EC) No 1881/2006**),** and after thermal treatment**,** these concentrations are four times as high as the ones before smoking. With regard to the maximum values defined by the Ivorian regulation, smoking increases by 2.5 times at most the initial concentration of BaP. The average concentration of Benzo(a)Pyrene found in *the* flesh of fish remains superior to the maximum limit value set by international authorities (Commission Regulation (EC) No

1881/ 2006**)**. Yet the flesh of fish contributes to the BaP daily intake of different consumers in proportions between 3 % (small consumers) and 14.8% (large consumers). The average intake estimated for fresh and smoked fish is respectively 10.69 and 47.4 ng/kg body weight/d. These intakes are very superior to the levels described by AFSSA in 2003 (0.67-1.83 ng/kg body weight/d). These values don't take other eaten foods into account.

Compared to the Toxicity Reference Value (TRV) established at 5 ng/kg body weight by the Netherlands Institute for Public Health and the Environment (RIVM) (**1**), the intakes estimated are at least three times as high as this reference value and are superior even to the intakes estimated for small consumers. Side effects are likely to occur. Between fresh and smoked condition, there are changes in the fish which may increase the risk factors, and consequently the risks to consumers; the risk factors are, among others, ancestral practices, types of vegetal products and their preparations before use to light fire for smoking. Given the carcinogenic and genetoxic properties of BaP (**1**), the toxicological risk also exists, and even chronic exposures to relatively low concentrations can generate cancer (chronic carcinogenic effect) as the molecules studied are molecules with no threshold effect (**8**).

5. Conclusion

The concentrations of BaP in 95% of the samples tested in fresh and smoked fish are above the maximum value set by the Ivorian and European regulations. The average intake of BaP estimated from the same samples for an adult is at least 3.6 times the Toxicity Reference Value. The risk is thus real if fish is the only animal protein present in consumers' diet. The quality control of fish is thus necessary; hence the interest of this work to assess the levels of contamination of BaP in smoked fish. Therefore, it is important to make the stakeholders of the smoked fish chain (fishermen, smokers, sellers) aware of the strict observance of good practices of heat treatment, train them to implement proper hygiene rules and take appropriate measures to ensure the traceability of smoked fish all along the chain, from the management of the raw material to its release for consumption.

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