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Contaminant intake from fuels used when grilling meats and stripping beef hides

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Abstract: Stripping skins, smoking and cooking are techniques often used for the preservation and consumption of foods of animal origin. In Côte d'Ivoire, in the District of Abidjan, particularly in the communes of Abobo and Port-Bouët, used tires, rubber debris and rubber wood are the fuels for stripping beef hides. The pickled and smoked skin, called "kplo", is widely consumed. The same goes for "choukouya", beef, sheep or goat meat cooked in artisanal metal ovens fueled mainly by rubber wood in the communes of Port-Bouët and Yopougon. These pickling and cooking processes generate fumes that may contain compounds that are toxic to human food. The objective of this study is to highlight the contributions of polycyclic aromatic hydrocarbons (PAHs) and trace metal elements (TMEs) from pickling and cooking fuels. To do this, a survey was carried out. The results show that rubber wood is the fuel mainly used both in cooking meat (70%) and in stripping skins (more than 50%). The fuels used in stripping (rubber wood, reclaimed wood, plastics, etc.) and in cooking meat (rubber wood, reclaimed wood) are sources of PAHs and TMEs that can induce carcinogenic effects or mutagens.

Keywords: *meats; skins; choukouya; kplo; contributions; fuels*

1. Introduction

Smoking and cooking are among the oldest methods of preserving foodstuffs of animal origin (Werlich, 2001; FAO, 2014), with a view to improving their availability. In Côte d'Ivoire, meat and offal are the subject of a poorly structured but fairly dynamic trade (Minagri, 2009; Tondel, 2019). Indeed, nearly 400 oxen are slaughtered per day at the main slaughterhouse in the city of Abidjan, located in the municipality of Port-Bouët, in unsanitary conditions (UOAMIB, 2015) generating a strong gastronomic activity. In particular, cooking meat and smoking beef hides in the District of Abidjan are quite lucrative activities for artisans. Concerning the grilled meat called "choukouya" and the beef skins called "kplo", which are very popular, many points of sale have been created. However, various fuels

which do not always comply with hygiene rules are often used to cook or pickle and smoke these foods. These mainly include rubber wood, used tires and plastics (Magazine Santé, 2015).

The use of these fuels by skin strippers and meat grillers is favored by several factors. The first relates. to intensive rubber cultivation in recent years in the country which has led to the felling of old trees with low latex production for use as lumber and fuel (CNRA, 2006; Ruf, 2008). The second is the availability of used tires from heavy car traffic, used among other fuels to burn ox, sheep and goat hides. The last factor, corresponding to the financial aspect, which is the satisfactory financial gain of craftsmen, seems to obscure the serious health risk that consumers run.

Indeed, resinous fuels and plastics used in pickling are likely to release toxic fumes containing carcinogenic and mutagenic PAHs and TMEs (INERIS, 2002; Aliapur, 2009), which can contaminate food. In addition, these chemical entities are teratogenic, reprotoxic and can cause neurological disorders and affect the immune system (Bismuth *et al*., 2000; OFSP, 2020). Also, according to Akwetey *et al*. (2013), the fuels used for pickling (firewood, plastics, tires) pose a risk to the health of consumers because they contain carcinogenic compounds such as dioxins, furans and polycyclic aromatic hydrocarbons.

In addition to food contamination, exposing consumers, craftsmen are also exposed by inhalation of fumes released at pickling and cooking sites.

In order to preserve the environment and the health of the population, the State conducts quality controls by applying health standards and raising awareness of good hygiene practices (CODINORM, 2024). In this context, improved fish smoking ovens have been built to reduce the release of PAHs and other pollutants (FAO and PNUE, 2023). However, for the grilling of meat and the pickling of animal skins, there is hardly any supervision of craftsmen aimed at the healthy processing of these foodstuffs. It is important to understand the extent of the contamination resulting from the fuels involved, especially since very few studies have been devoted to this subject in the country, to our knowledge. Previously, Dibi *et al*. (2017) had conducted a study of the contamination of fresh meat as well as grilled meat. But it only looked at the bacteriological aspect of the contamination. The present study proposes to look at chemical contamination due to fuels consisting of rubberwood, rubber scrap and plastics. Obtaining qualitative and quantitative data on contamination due to the different fuels used in the pickling and cooking process is crucial for a possible decision by the health authorities. It contributes to the health of populations. This work focuses on food contamination and the perception of risks due to the use of rubber wood, rubber debris and various plastics, through a food survey. The objective of this study is to highlight the contributions of PAHs and TMEs from the fuels used to pickle beef skins and those from grilling meat.

2.1 Presentation of the study area

The study took place in the Abidjan district, in the Republic of Côte d'Ivoire. Three municipalities in the district were selected, namely Abobo, Port-Bouët and Yopougon. This choice was motivated by the intensity of stripping and restoration activities in these municipalities. Indeed, they are heavily dominated by humans with a significant concentration of restaurants and grilled meat sales outlets, particularly in Abobo and Yopougon. In addition, the commune of Port-Bouët is home to the slaughterhouse of the city of Abidjan around which many commercial and gastronomic activities are developed. Different sites were identified in each municipality depending on the nature of the matrix to be collected; these are restaurants selling placaly (cassava paste), points of sale of meat cooked on a grill and pickling places. **Figure 1** presents the study municipalities.

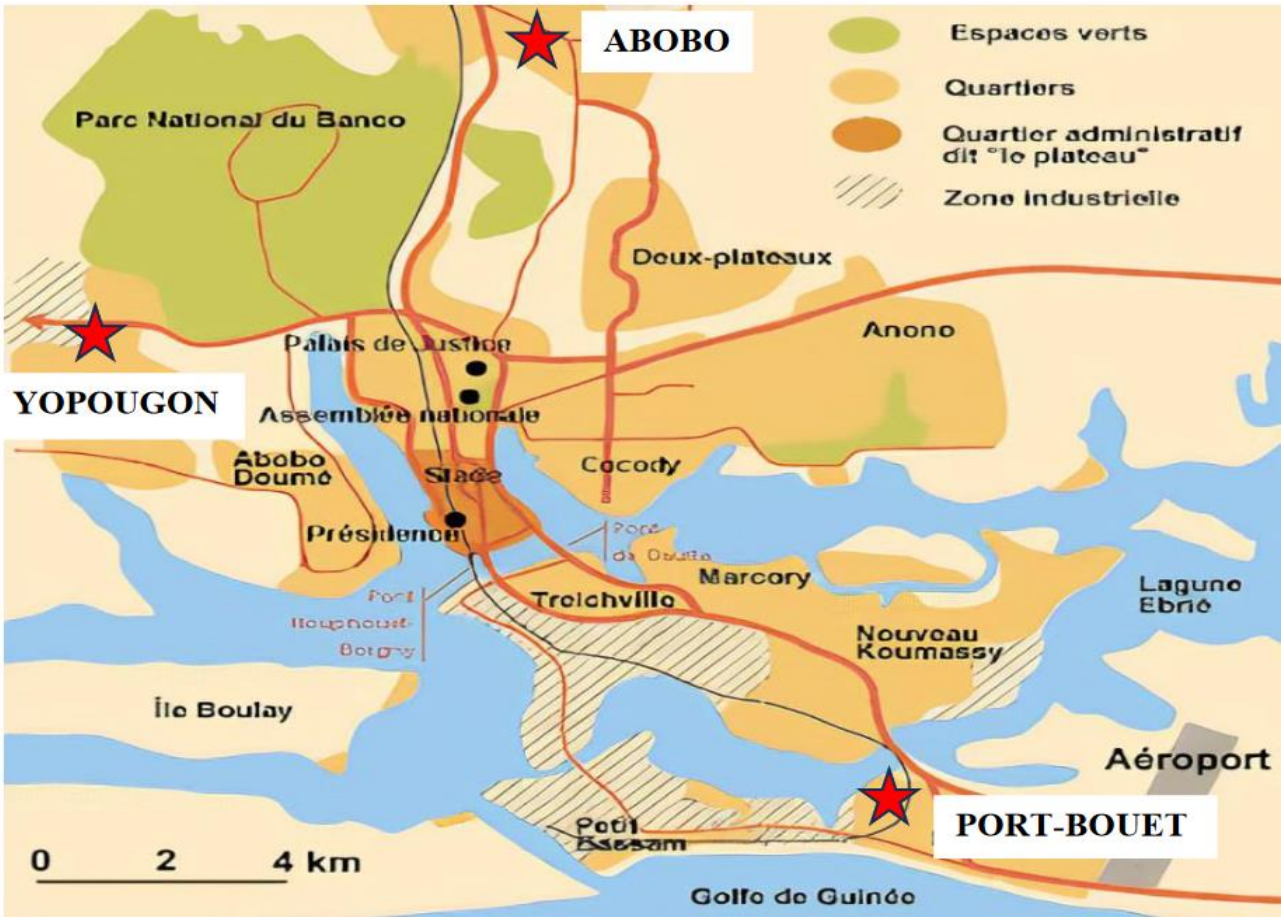

Figure 1. Map of the city of Abidjan presenting the study communes (Source: RFI http://www1.rfi.fr/actufr/articles/059/article_31573.asp)

2.2 Hardware

Survey material

It essentially consists of a Summit laboratory balance with a capacity of 1000 g, precision 0.01 g for weighing meat and skin samples and survey sheets.

Biological material

Biological material includes beef meat and hides.

2.3 Methods of investigation

Phases of the investigation

In the case of this study, the survey took place in the period from April 2015 to July 2015, sufficient to better observe the artisans according to the availability of various fuels such as rubber wood, wood of mangrove trees, boards from evictions, tires, plastics, etc. In this survey, information on the nature of fuels and technologies for stripping skins and cooking meat was collected and analyzed.

Choice of study population

The survey was carried out among 150 pickling artisans (50 artisans per municipality), 150 grill cooking artisans or choukouya sellers (50 artisans per municipality).

Investigative techniques

The techniques used focused on interviews and interviews, observation of the different sites of skin stripping and meat grilling.

The questionnaire concerned skin stripping and meat grilling sites. The investigation consisted of identifying the fuels used for stripping animal skins as well as those used for grilling meat. It also concerned the type of fuel used mainly by artisans (buried tires, rubber wood, plastics, etc.). In addition, the perception of the health risk *via* the stripping activity was also collected from the strippers.

3. Results and Discussion

3.1 Types of fuels used for skin stripping

The fuels used by artisans to strip the skins are diverse and vary depending on the municipality. They are presented in **Figure 2.**

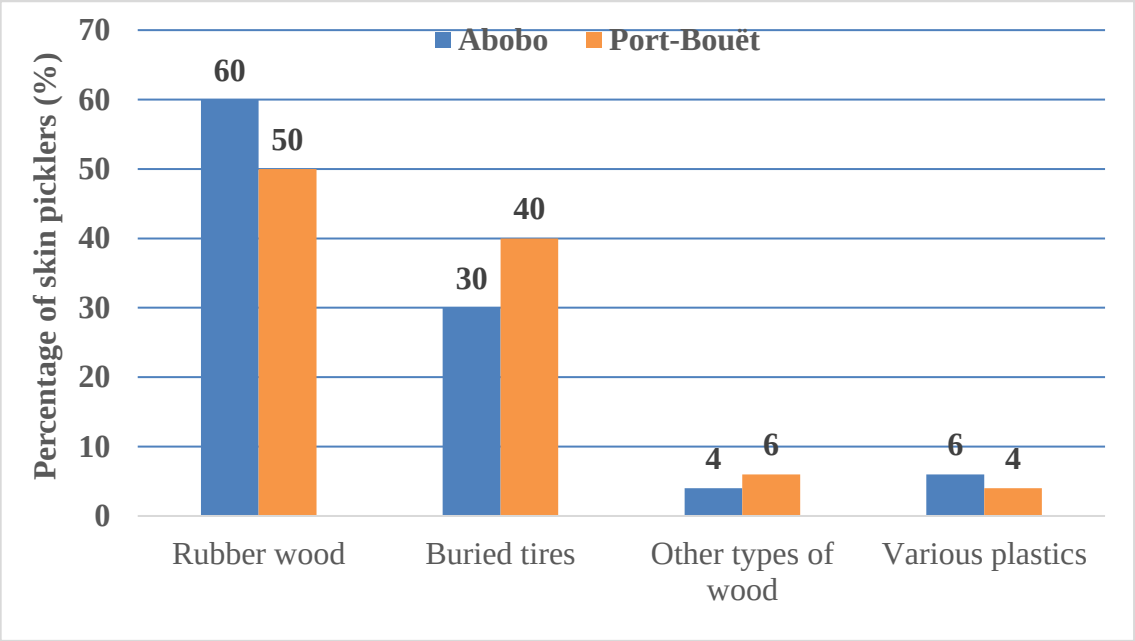

Figure 2. Fuels used for stripping beef hides

The results show that more than 50% of stripping craftsmen say they mainly use rubber wood. The use of this fuel is much greater in the commune of Abobo. Buried tires come in 2nd place among fuels used. In fact, between 30% and 40% of craftsmen say they mainly use buried tires. Recovered wood from clearance operations is also used. Other plastic materials are also used for skin stripping. These include the plastic casings of televisions, computers, radio receivers, storage batteries, drums, buckets, etc. The high use of rubber wood and used tires could be explained by their relatively lower costs and the significant lower calorific value (LCV) of rubber (40,000 kJ/kg) (Chanclou, 2000) that they contain. This use of various fuels that do not comply with hygiene rules during pickling has also been noted by Akwetey *et al.* (2013) and Dada *et al.* (2018). These authors mentioned the stripping of goat skin with plastics and tires by mainly urban populations, suffering from a shortage of firewood.

3.2 Types of fuels used for grilling meat

Figure 3 shows the different types of fuels used for the preparation of "choukouya". The results of the survey show that cooking is done exclusively with wood. Also, as in the case of skins, rubber wood is the fuel mainly used in the two municipalities selected which are Port-Bouët and Yopougon (around 70% on average). The intensive use of rubber wood for cooking meat could be explained by its calorific value, its lower cost and its wide availability in the city of Abidjan close to the rubber plantations of which the wood is the base product of a tree grown for its latex.

Along these same lines, rubber wood has always been used as a cheap source of wood fuel in most countries where plantations are numerous. It is also used on an industrial scale, for baking bricks and drying tobacco (Killmann, 1992; Hong, 1995). Furthermore, among the fuels used by the craftsmen are recovered wood, resulting from eviction operations. It should be noted that they are often covered with paint or varnish, which makes them potential sources of metals, particularly lead.

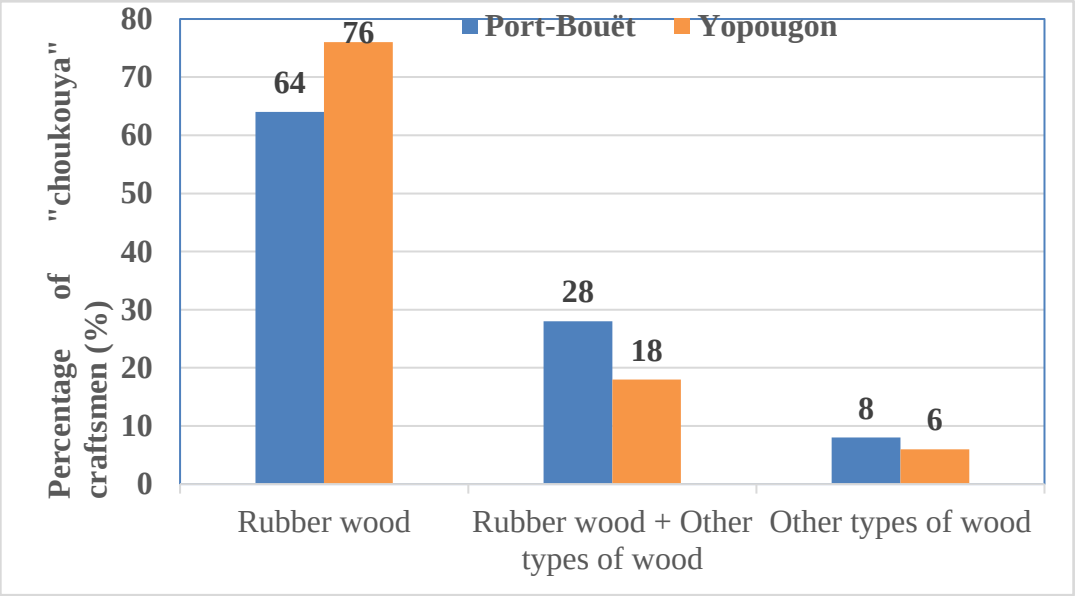

Figure 3. Fuels used for the preparation of "choukouya"

3.3 Risk perception

The investigation showed that no stripper from the two sites is aware that there is a health risk in consuming the skins. However, 38% of strippers in Abobo are aware of diseases linked to stripping activity such as respiratory diseases and cancer. This rate is 42% in Port-Bouët. Despite this fact, no stripper uses mufflers whatever the intensity of the smoke given off by the fuels. Those who claim to have already been ill while carrying out their activity constitute 66% and 54% respectively in Abobo and Port-Bouët. It also follows from the survey that almost all consumers are unaware of the dangers linked to the consumption of meat and skins treated with rubber wood, reclaimed wood often painted or varnished, tires or with various plastic materials. These different fuels are not recommended for pretreatment and cooking. In fact, the wood to be used should not be resinous; also, the use of fuels other than wood and other plant materials for smoking is not recommended. For example, diesel, rubber (tires) and waste oils should generally not be used, even as a partial component, as they can cause a considerable increase in the levels of contaminants such as PAHs (FAO/WHO, 2012). Furthermore, the use of used tires could constitute a significant source of TMEs and PAHs. In fact, the cadmium and lead contents of used car tires are respectively 10 mg/kg and 50 mg/kg (OFEFP, 2001). Also, PAHs of fossil origin are also included in the composition of extender oils, which are mixed with rubbers used in the manufacture of tires (CITEPA, 2010).

3.4 PAHs contents provided by cooking with rubber wood in grilled meat

PAHs analysis results in meat grilled with rubber wood (Yaya *et al.*, 2019a) are presented in the following **Table 1.**

Table 1. Concentrations in µg/kg of the different PAHs determined in grilled meat samples

	B(a)P	B(b)F	B(k)F	B(ah)A	CHR	I(cd)P	B(a)A	B(ghi) Pery	Fluoran -thene
Municipality of Port-Bouët	13.45	34.38	440.27	17.97	57595.16	ND	221.48	ND	1302.38
Municipality of Yopougon	15.55	65.52	47.11	10.76	1939.64	ND	20.28	ND	1261.41
Average levels across all municipalities	14.5	49.95	243.69	14.36	29767.4	ND	120.88	ND	1281.89

ND: not determined

From these results, the average intakes of indicator PAHs by the fuels used (rubber wood) for grilling meat were determined and the results are presented in the **Table 2.** The average concentrations of these PAHs in the different states of the meat are also shown.

Table 2. Average intakes of indicator PAHs by the fuels used (rubber wood) in grilled meat

	Chrysene (µg /kg)	Benzo(a) Anthracene (µ g/kg)	Benzo(b) Fluoranthene (µ g/kg)	Benzo(a)pyrene (µg /kg)	∑4PAH $_{ind}$ (µ g/kg)
PAHs in grilled meat	29767.4	120.88	49.95	14.5	29952.73
PAHs in fresh meat	358.24	101.89	6.66	5.64	472.43
PAHs intake	29409.16	18.99	43.29	8.86	29480.3

Fresh meat samples have the lowest PAHs concentrations with contents varying from 5.64 to 358.24 µg.kg $^{-1}$. The samples of meat grilled with rubber wood had the highest PAHs concentrations varying from 14.5 to 29767.4 µg.kg $^{-1}$. Contaminant intakes due to cooking meat using the grill technique were determined from the difference between the concentrations measured in samples of fresh meat and grilled meat. It appears that a large part of the PAHs found in grilled meat are provided by rubber wood. The quantities of PAHs released by the combustion of rubber wood and transmitted to meat are respectively 29409.16 µ g/kg; 43.29 µg /kg; 18.99 µ g/kg and 8.86 µ g/kg for chrysene, benzo(b)fluoranthene, benzo(a)anthracene and benzo(a)pyrene. Thus, cooking meat with rubber wood transmits 82 times the quantity of chrysene, 7 times that of benzo(b) fluoranthene and 2 times that of benzo(a) pyrene, contained in fresh meat. Furthermore, polycyclic aromatic hydrocarbons (PAHs) molecules were found at various concentrations.

The toxicity of these pyrolytic PAHs requires monitoring by health agencies (Schroeder, 2010). Of these, benzo(a)pyrene is the most toxic due to its ability to form adducts with DNA, which can induce mutagenic and carcinogenic effects. For a long time, it was therefore used as the only marker of the presence of PAHs. However, it has been shown that its monitoring alone is insufficient and that the sum of the levels of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene must also be considered (Engel *et al*., 2014). The concentration of benzo(a)pyrene and the sum of the concentrations of the 4 reference PAHs (benzo(a)pyrene; benzo(a)anthracene; benzo(b) fluoranthene and chrysene) exceed their respective standards (2 µg/kg and 12 µg/kg) (EC, 2011)**.** Taking into account this exceeding of the PAHs MRLs as well as the daily quantities consumed of meat, undesirable effects may appear. They are hepatic, hematological and immunological (OFSP, 2012). In

addition, PAHs lead to an excess individual risk likely to induce carcinogenic and mutagenic effects (Yaya *et al.*, 2023).

3.5 TMEs contents provided by cooking with rubber wood in grilled meat

Table 3 below presents the results of analysis of TMEs in meat grilled with rubber wood (Yaya *et al.*, 2019b).

Table 3. Contents in mg/kg of the different TMEs determined in grilled meat samples

	Pb (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
Municipality of Port-Bouët	0.490	0.008	0.089
Municipality of Yopougon	0.446	0.005	0.083
Average levels across all municipalities	0.468	0.007	0.086

From this table, the average TMEs intakes from the fuels used (rubber wood) for grilling meat were determined. The results are shown in **Table 4.**

Table 4. Average TMEs intakes in grilled meat using rubber wood

	Pb (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
Grilled meat	0.468	0.007	0.086
Fresh meat	0.467	0.011	0.044
Average intakes in TMEs	0.001	nd	0.042
Standard deviation	0.001	nd	0.035

nd: not detected

The average TMEs intake after grilling meat is noticeable for lead and mercury; however, they are not accurate for cadmium. Taking into account all TMEs, these contributions are not negligible. They could be explained essentially by the materials of the metal cooking ovens such as the barrels, some of which have paint that may contain lead and others which previously contained various chemicals.

3.6 TMEs contents added to the skins by tire stripping

TMEs were measured in beef hides stripped from tires by atomic absorption spectrophotometry (Yaya *et al.*, 2019b) and the results are presented in **Table 5.**

Table 5. Contents in mg/kg of the different TMEs determined in the skin samples

	Pb (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
Municipality of Abobo	0.605	0.012	0.077
Municipality of Port-Bouët	1,457	0.011	0.128
Average levels across all municipalities	1.031	0.011	0.103

The average TMEs intakes in the skin samples were determined by making the difference between the contents in the treated skins and those in fresh skins which, by working hypothesis, were assumed to have the same level of initial contamination as fresh meat. **Table 6** shows the values obtained.

Table 6. Average TMEs intakes in samples of beef hides treated using

	Pb (mg/kg)	Cd (mg/kg)	Hg (mg/kg)
Treated skin	1.031	0.011	0.103
Fresh skin	0.467	0.011	0.044
Average intakes in TMEs	0.564	0.000	0.059
Standard deviation	0.146	0.000	0.002

The average intake of TMEs after treatment of the skins (stripping and cooking) is net for lead and mercury. However, it is below the detection limit for cadmium. The values of TMEs intakes are higher than those found in the case of grilled meat. This difference could be due to the cooking method.

These calculated TMEs contributions in the skin samples analyzed could be explained essentially by the fuels used for stripping. Indeed, the combustion of used tires produces highly toxic substances including TMEs (INERIS, 2009). Skin samples are the most contaminated in TMEs and lead remains the most accumulated metal of the three TMEs, with contents higher than the maximum residue limit (MRL) which is 0.1 mg/kg (EC, 2006). Mercury and cadmium levels remain below their limits, which are 0.5 mg/kg (Thibaud, 1971) and 0.05 mg/kg (EC, 2006) respectively.

The high value of the average lead content in the skin samples would be due on the one hand to the diffusion of this pollutant in the skin and muscle (Miquel, 2001), on the other hand by its significant quantity in the fuels used (used tires, plastic materials from old accumulator batteries) (IN ERIS, 2009). Uwem Edet *et al.* (2024) obtained similar results, above the MRL, for the lead. They obtained an average concentration (0.20 ± 0.02 mg/kg) in meat with goat skin cooked using car tires and plastics.

Furthermore, the combustion of rubber and rubbery waste generates abundant, very dirty and nauseating fumes. From a chemical point of view, they contain carbon oxides (CO and CO_2); light hydrocarbons, especially aromatic (benzene, toluene, etc.); oxygenated organic compounds (aldehydes, carboxylic acids, etc.); sulfur dioxide (SO_2); various sulfur derivatives such as mercaptans (R-SH), carbon sulphide (CS_2), hydrogen sulphide (H_2S); soot (black carbon deposit) (INERIS, 2009). As for the plastic materials used for stripping, their combustion can also release numerous products of varying toxicity. Indeed, the burning of plastics releases toxic gases into the atmosphere such as dioxins, furans, mercury and polychlorinated biphenyls, and constitutes a threat to vegetation, as well as to the health of humans and animals (Verna *et al.*,2016; UNEP, 2019).

Conclusion

Meat cooking is done exclusively with wood. Rubber wood is the fuel mainly used both in cooking meat (70%) and in stripping skins (more than 50%). Buried tires come in 2nd place among the fuels used (between 30% and 40%). Pickling fuels (rubber wood, reclaimed wood, plastics, etc.) and cooking meat (rubber wood, reclaimed wood) are sources of PAHs and TMEs.

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