

Nutritional Quality and Heavy Metal Contamination of Smoke-Dried Beef Skin ("Kplô") Marketed in Abidjan, Côte d'Ivoire

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Abstract

Background: Smoke-dried beef skin, commonly known as "kplô", is widely consumed in Côte d'Ivoire and constitutes a traditional animal-derived food. However, some smoking and processing practices may affect its chemical safety. This study evaluated the nutritional quality and occurrence of selected toxic metals in smoke-dried beef skin marketed in Abidjan.

Materials and Methods: A socio-demographic survey was conducted among 116 respondents, including actors involved in smoking and marketing and consumers. Smoke-dried beef skin samples collected from Port-Bouët and Abobo were analyzed for moisture, proteins, lipids, fibers, ash, amino acids, minerals, cadmium, lead, and mercury.

Results: The survey showed that 73% of respondents consumed smoke-dried beef skin. Moisture contents were $42.03 \pm 1.55\%$ and $42.02 \pm 2.42\%$ in samples from Port-Bouët and Abobo, respectively. Protein contents ranged from 36.99 ± 0.67 to $45.41 \pm 0.39\%$, lipids from 1.69 ± 0.06 to $3.02 \pm 0.06\%$, and ash from 2.36 ± 0.12 to $2.53 \pm 0.12\%$. Essential amino acids, including lysine, leucine, and histidine, were detected, together with phosphorus, potassium, calcium, iron, magnesium, sodium, zinc, copper, and manganese. Cadmium and lead concentrations ranged from 1.32 ± 0.07 to $1.71 \pm 0.07 \mu\text{g}/100 \text{ g}$ and from 3.48 ± 0.50 to $4.45 \pm 0.75 \mu\text{g}/100 \text{ g}$, respectively, whereas mercury was not detected.

Conclusion: Smoke-dried beef skin provides proteins, essential amino acids, and minerals, with relatively low measured cadmium and lead concentrations. However, sanitary safety cannot be fully established because other smoking-related contaminants, particularly polycyclic aromatic hydrocarbons, were not investigated. Improved smoking and hygiene practices, including avoiding rubber and other non-wood fuels, are recommended.

Key Word: Smoked Beef Skin; Nutritional Quality; Biochemical Parameters; Heavy Metals; Sanitary Quality

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I. Introduction

The Ivorian livestock policy, initiated in the post-independence years, was initially limited to the creation of breeding stations and centers (Kouablé and Tré Bi, 2014). However, it was hampered by the various socio-political and economic crises the country experienced. Consequently, this policy failed to ensure national self-sufficiency in animal products. Indeed, meat supply relies largely on imports of live cattle from neighboring Sahelian countries, structuring the major cross-border commercial corridors of the region (ECDPM, 2021; FAO, 2020). Subsequently, faced with supply crises caused, among other things, by the 1972-1973 drought, the State elevated livestock farming to the rank of national priority, leading to the creation in 1972 of the Animal Production Development Company (SODEPRA), responsible for research, extension, and the implementation of sectoral projects (Kouablé and Tré Bi, 2014). Thanks to these initiatives, the national cattle population, estimated at 356,770 head in 1974, rose to 1,035,000 head in 1990, reaching over 1.5 million head in the early 2010s (Kouablé and Tré Bi, 2014). Nevertheless, despite these structuring efforts, Côte d'Ivoire remains heavily dependent on international trade to meet its needs for animal foodstuffs. For example, it imports about 60% of its meat consumption and 95% of its milk consumption. Consequently, this high dependence exposes the local supply chain to fluctuations in external markets, leading to direct repercussions on household purchasing power and a constant rise in the prices of live animals and meat (Silué, 2009). Faced with the high cost of premium cuts of meat, urban dietary habits have undergone profound changes. These are characterized by a nutritional transition toward alternative and more accessible protein sources, commonly grouped under the term "fifth quarter" (Bricas *et al.*, 2016; Silué, 2009). Furthermore, the latter encompasses offal and slaughterhouse by-products, traditionally utilized after specific culinary processing (Crapelet, 1965). Among these by-products, smoke-dried beef skin, designated by the vernacular term "kplô", occupies a prominent place in diets in Côte d'Ivoire (Koffi *et al.*, 2021).

It is appreciated not only for its modest cost, but is also anchored in urban socio-cultural habits. Thus, it is omnipresent in domestic cooking, particularly to accompany popular cassava-based dishes such as *placali*, as well as during major festive events (N'Guessan *et al.*, 2019). Originating from municipal slaughterhouses, raw beef skin undergoes a crucial processing step before being placed on the market: fire-scraping (Kouamé *et al.*, 2022). In this regard, while the exclusive use of firewood is the recommended traditional method, high urban demand and the search for profitability have led many actors in the sector to use heterogeneous recovery materials. These notably include rubber debris, plastics, and old tires to accelerate combustion or perfect the appearance of the product (Yaya *et al.*, 2020). However, low-temperature incineration of these synthetic polymers and industrial wastes generates complex fumes rich in formidable chemical contaminants, namely polycyclic aromatic hydrocarbons (PAHs) and traces of toxic heavy metals (lead, cadmium, mercury) (Dago *et al.*, 2020; Laureys, 2004). Consequently, chronic exposure to these toxic substances represents a dual public health challenge: a major occupational hazard for artisans exposed to combustion fumes, and a chronic toxicological risk for the final consumer via the ingestion of contaminated foodstuffs (Akpato *et al.*, 2018). Given the growth of the "kplô" sector, the scale of its consumption in Ivorian households, and the potential dangers associated with unregulated smoking practices, it is essential to rigorously evaluate its nutritional quality and sanitary safety. It is precisely within this perspective that the present study is framed. On the one hand, it aims to document the socio-economic organization of the sector through a survey on the production, processing, and marketing of smoked beef skin. On the other hand, it aims to characterize its overall biochemical profile (major compounds, minerals, and amino acid profile) while quantifying toxic metal residues (lead, cadmium, mercury)

II. Material And Methods

Biological Material

The biological material consists of smoke-dried beef skins ("kplô") collected in two representative communes of the District of Abidjan (Port-Bouët and Abobo), as presented in Figure 1.



Figure 1: Photograph of fresh beef skin (a) and smoke-dried beef skins (b)

Methods

Survey

A cross-sectional study was conducted among 116 sector actors and consumers using a questionnaire to evaluate the frequency of consumption (F) and smoking practices:

$$F = \frac{n}{N} \times 100 \quad (1)$$

Where: F: frequency; N: total population size; n: relative population size.

Sample preparation

The samples were packaged in airtight containers and transported to the laboratory. After cutting, moisture content was determined on aliquots of the original smoke-dried beef skin samples before oven-drying for sample preparation. The remaining samples were then oven-dried at 60 °C for 72 h, ground, and sieved through a 50 µm mesh to obtain a homogeneous powder for subsequent analyses.

Biochemical analyses

Physicochemical and biochemical analysis methods

All analytical determinations were performed in five replicates. Moisture content was determined by oven drying at 105°C to constant mass, and ash by incineration at 550°C for 4 h (AOAC, 1990). Crude fibers were measured by successive acid and alkaline digestion followed by incineration of the residue (AOAC, 1990). Total lipids were extracted using a Soxhlet extractor with hexane for 7 h (AOAC, 1990). Crude protein content was determined using the Kjeldahl method with a nitrogen-to-protein conversion factor of 6.25 (AOAC, 1990).

Mineral determination

Mineralization for mineral determination was conducted by digestion with a mixture of perchloric, nitric, and sulfuric acids (AOAC, 1990). Mineral elements were quantified by flame atomic absorption spectrophotometry (Varian AA.20). Cadmium, lead, and mercury concentrations were determined according to the AOAC (1999) method, based on acid digestion followed by atomic absorption spectrometry (AAS, Shimadzu AA-7000). Phosphorus was determined by the vanado-molybdc colorimetric method (Tausky and Shorr, 1953).

Identification and quantification of amino acids

Total amino acid extraction was carried out by acid hydrolysis. The resulting hydrolysate (6 M HCl with 1% phenol at 150 °C for 60 min) was analyzed by high-performance liquid chromatography (HPLC, Pico-Tag system, Waters, USA) coupled with a UV detector set at 280 nm. Identification was performed by comparing retention times with standards, and quantification using the formula:

$$CE = \frac{AireE \times CT}{Aire T} \quad (2)$$

Where: CE: sample concentration; Aire T: peak area of the standard; Aire E: peak area of the sample; CT: concentration of the standard.

Statistical analysis

Statistical analyses were performed using STATISTICA 7.1 software. Data were expressed as mean ± standard deviation (n = 5). Differences between mean values from Port-Bouët and Abobo were assessed using Student's t-test, with statistical significance set at $p \leq 0.05$.

III. Result

Socio-demographic characteristics of beef skin smoke-dryers

Distribution of beef skin dryers by age group and sex

The proportion of beef skin dryers varies according to age group (Figure 2). The most represented bracket is 21-35 years old, recording the highest rate at 54.12%. Conversely, the lowest proportion is observed among subjects aged 20 years or younger.

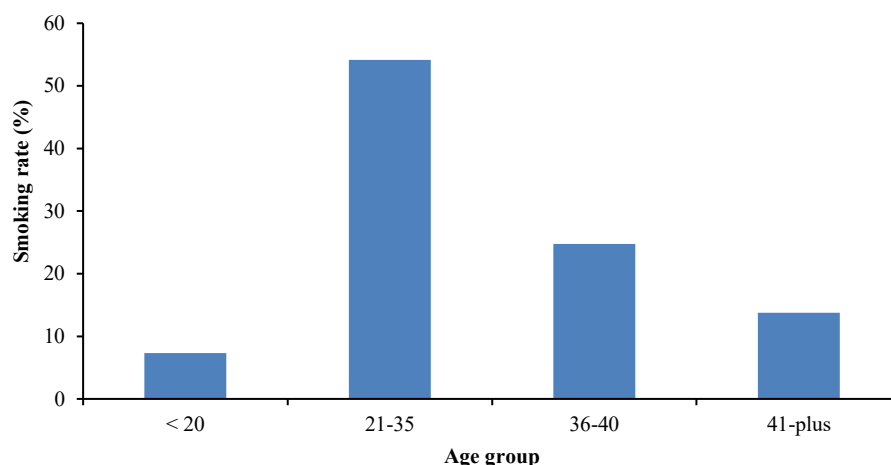


Figure 2: Distribution of beef skin dryers by age group

Distribution of beef skin dryers by nationality

The distribution of actors according to nationality reveals a clear predominance of foreign labor (Figure 3). Non-Ivorian dryers represent the largest proportion at 82.56%, while dryers of Ivorian nationality account for only 17.43%. Furthermore, these operators source their supply exclusively from the slaughterhouses of their respective localities.

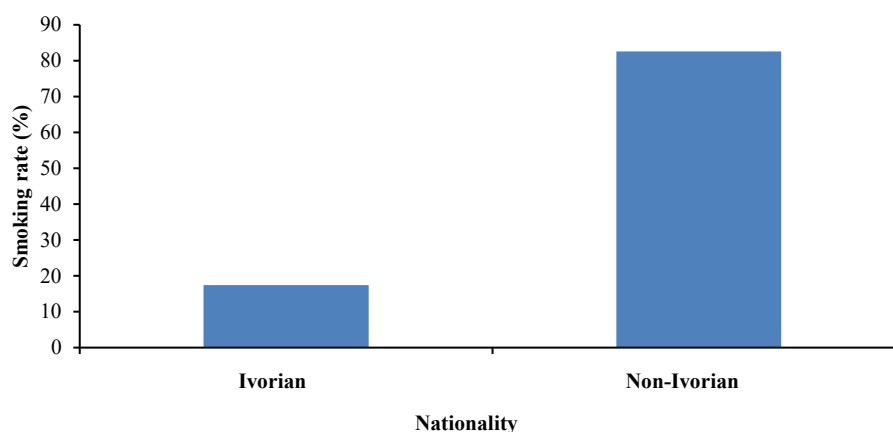


Figure 3: Distribution of beef skin dryers by nationality

Distribution of beef skin dryers by daily income

The analysis of dryers' daily incomes shows disparities (Figure 4). The income bracket below 5,000 FCFA is the most frequent, concerning 50.45% of the actors. It is followed by the income class between 5,000 and 10,000 FCFA, which represents 33.94% of the workforce.

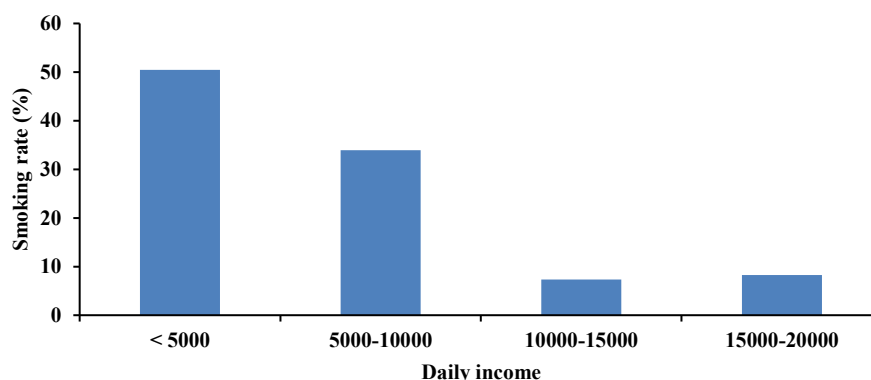


Figure 4: Distribution of beef skin dryers by daily income

Distribution of beef skin dryers by type of treatment and fuels used

Survey data distinguish two main modes of skin preparation before smoking: indirect treatment, which consists of cleaning and depilating the skin beforehand, and direct treatment, where the skin is smoked directly without prior cleaning. These observations show that the direct smoking method is the most practiced (51.37%), slightly ahead of the method with prior cleaning (48.62%). Regarding the fuels used for combustion, two main combinations were identified. The joint use of wood and dry rubber residues predominates with a proportion of 51.37%, while the combination of wood and beef bones lags slightly behind (48.62%). Finally, for the preservation of dried products, actors use two main types of containers, namely bags and drums.

Socio-demographic study of dried beef skin consumers

Distribution of dried beef skin consumers by sex

The consumption of dried beef skins is practiced by both genders, with a slight female predominance. Women show the highest consumption rate (51.33%), compared to men who record a proportion of 48.66%.

Distribution of smoked beef skin consumers by age group

The consumption of "kplô" varies significantly from one age group to another (Figure 5). The population aged 21 to 35 ranks as the largest consumer with 48.66%, followed by the 36-40 age bracket, which represents 25.44% of consumers.

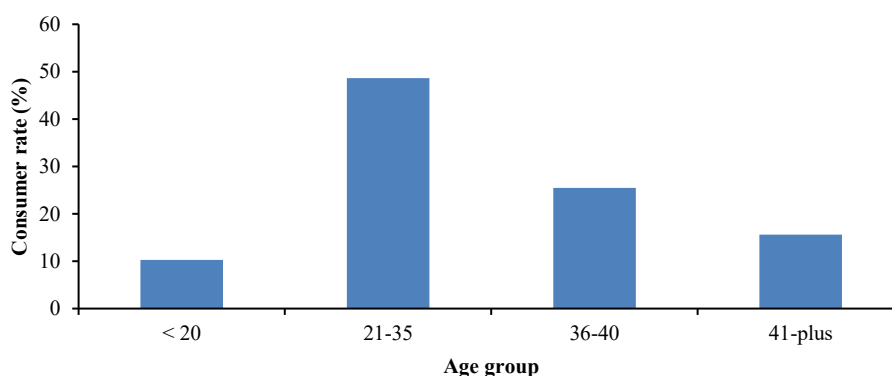


Figure 5: Distribution of dried beef skin consumers by age group

Distribution of culinary preference level by sex

The analysis of culinary preferences showed a marked preference for seed sauce ("sauce graine") among both men and women (Figure 6). Among men, 73.39% preferred beef skin served with seed sauce, compared with 26.60% who preferred okra sauce ("sauce gombo"). A similar but more pronounced trend was observed among women, with 86.95% preferring seed sauce and only 13.04% preferring okra sauce.

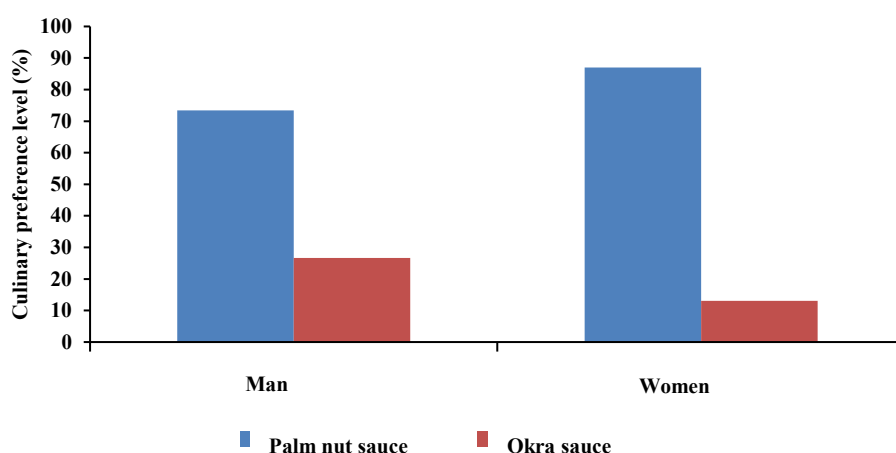


Figure 6: Distribution of culinary preference level by gender

Distribution of culinary preference level by age group

Culinary preferences varied across age groups (Figure 7). Among consumers under 20 years of age, 24% preferred okra sauce. The highest proportion of consumers preferring seed sauce was observed in the 21-35-year age group (50.25%). Among consumers aged 36-40 years, 25.12% preferred seed sauce, while 28% preferred okra sauce. In the 41 years and above age group, the corresponding proportions were 16.08% for seed sauce and 12% for okra sauce.

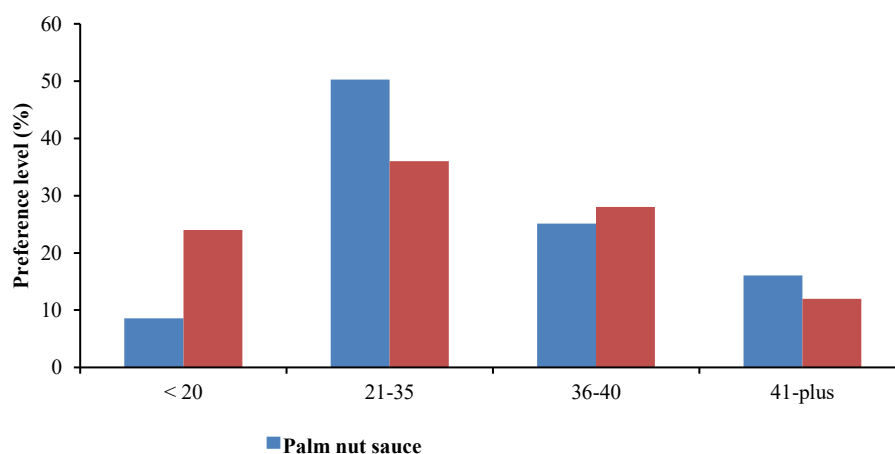


Figure 7: Distribution of culinary preference level by age group

Biochemical characteristics of smoke-dried beef skin

The moisture contents of smoke-dried beef skin were $42.03 \pm 1.55\%$ in Port-Bouët and $42.02 \pm 2.42\%$ in Abobo (Table 1). Statistical analysis revealed no significant difference between these values ($p > 0.05$). Crude protein contents were $36.99 \pm 0.67\%$ in Port-Bouët and $45.41 \pm 0.39\%$ in Abobo, with a significant difference between the two localities ($p < 0.05$). Total lipid contents were $3.02 \pm 0.06\%$ in Port-Bouët and $1.69 \pm 0.06\%$ in Abobo, also showing a significant difference between the two localities ($p < 0.05$). Crude fiber contents ranged from $0.03 \pm 0.01\%$ in Abobo to $0.06 \pm 0.01\%$ in Port-Bouët, with no significant difference between the two localities ($p > 0.05$). Ash contents were $2.36 \pm 0.12\%$ and $2.53 \pm 0.12\%$ in Port-Bouët and Abobo, respectively, and did not differ significantly ($p > 0.05$).

Table 1: Biochemical composition of smoke-dried beef skin

Parameters (%)	Port-Bouët	Abobo
Moisture	42.03 ± 1.55^a	42.02 ± 2.42^a
Proteins	36.99 ± 0.67^b	45.41 ± 0.39^a
Lipids	3.02 ± 0.06^a	1.69 ± 0.06^b
Fibers	0.06 ± 0.01^a	0.03 ± 0.01^a
Ash	2.36 ± 0.12^a	2.53 ± 0.12^a

Mean $\pm$ Standard deviation ($n = 5$). Values in the same row affected by the same letter are not significantly different ($p > 0.05$) from each other according to Student's *t*-test.

Amino acid composition of smoke-dried beef skin

Among the essential amino acids, lysine ranged from 3.90 ± 0.20 mg/g DM (Abobo) to 4.48 ± 0.081 mg/g DM (Port-Bouët), while leucine ranged from 2.47 ± 0.041 mg/g DM (Abobo) to 3.76 ± 0.025 mg/g DM (Port-Bouët) (Table 2). Among the non-essential amino acids, proline ranged from 1.29 ± 0.02 mg/g DM in Abobo to 2.08 ± 0.10 mg/g DM in Port-Bouët. The statistical analysis revealed significant differences between samples from the two localities.

Table 2: Amino acid composition of smoke-dried beef skin

Amino acids (mg/g DM)	Port-Bouët	Abobo
Lysine*	4.48 ± 0.081^a	3.9 ± 0.20^b
Threonine*	2.08 ± 0.13^a	1.93 ± 0.02^b
Valine*	2.40 ± 0.21^b	2.87 ± 0.40^a
Leucine*	3.76 ± 0.025^a	2.47 ± 0.041^b
Isoleucine*	2.32 ± 0.13^b	2.65 ± 0.04^a
Tryptophan*	0.56 ± 0.14^a	0.43 ± 0.020^b
Methionine*	1.20 ± 0.02^b	1.25 ± 0.02^a
Phenylalanine*	2.24 ± 0.18^b	2.97 ± 0.04^a
Histidine*	1.52 ± 0.021^a	1.50 ± 0.40^b
Arginine	3.12 ± 0.14^b	3.34 ± 0.18^a
Alanine	2.88 ± 0.12^a	2.62 ± 0.15^b
Proline	2.08 ± 0.10^a	1.29 ± 0.02^b
Aspartic acid	4.56 ± 0.15^a	3.93 ± 0.020^b
Glycine	2.41 ± 0.07^b	2.46 ± 0.012^a
Cystine	0.64 ± 0.03^b	0.76 ± 0.03^a
Serine	0.76 ± 0.09^a	0.68 ± 0.010^b
Glutamic acid	5.48 ± 0.24^a	4.20 ± 0.014^b
Tyrosine	1.76 ± 0.06^a	1.53 ± 0.05^b
Ess. AA / Total AA	0.46	0.48

Mean $\pm$ Standard deviation ($n = 5$). Values in the same row affected by the same letter are not significantly different ($p > 0.05$) from each other according to Student's *t*-test. AA: amino acids; *: essential amino acid.

Mineral composition of smoke-dried beef skin

Mineral analysis revealed the presence of macroelements (P, K, Na, Ca, and Mg) and trace elements (Zn, Mn, Fe, and Cu) in smoke-dried beef skin samples from both localities (Table 3). Among the macroelements, phosphorus (P), potassium (K), sodium (Na), and magnesium (Mg) contents were higher in samples from Port-Bouët, with respective values of 250 ± 15.10 , 350.06 ± 4.90 , 98.07 ± 3.10 , and 42.08 ± 1.70 mg/100 g. In contrast, among the trace elements, iron (Fe), manganese (Mn), and zinc (Zn) contents were higher in samples from Abobo, with respective values of 67.42 ± 1.30 , 3.02 ± 0.50 , and 14.75 ± 2.90 mg/100 g. Statistical analysis revealed significant differences ($p < 0.05$) in mineral contents between the two localities.

Table 3: Mineral composition of smoke-dried beef skin

Minerals (mg/100g)	Port-Bouët	Abobo
P	250 ± 15.10^a	198 ± 10.70^b
Ca	58.35 ± 1.20^b	72.16 ± 2.30^a
Fe	51.50 ± 2.90^b	67.42 ± 1.30^a
Mn	02.94 ± 0.04^b	03.02 ± 0.50^a
Cu	09.15 ± 2.10^a	06.79 ± 0.90^b
Zn	12.14 ± 0.50^b	14.75 ± 2.90^a
Na	98.07 ± 3.10^a	96.12 ± 1.40^b
K	350.06 ± 4.90^a	294 ± 5.90^b
Mg	42.08 ± 1.70^a	37.01 ± 1.10^b

Mean $\pm$ Standard deviation ($n = 5$). Values in the same row affected by the same letter are not significantly different ($p > 0.05$) from each other according to Student's *t*-test.

Heavy metal composition of smoke-dried beef skin

The analysis of toxic heavy metals revealed the presence of cadmium and lead in smoke-dried beef skin samples from both localities (Table 4), whereas mercury was not detected. Cadmium concentrations ranged from 1.32 ± 0.07 μ g/100 g in Abobo to 1.71 ± 0.07 μ g/100 g in Port-Bouët, with no significant difference between the two

localities ($p > 0.05$). In contrast, lead concentrations ranged from $3.48 \pm 0.50 \mu\text{g}/100 \text{ g}$ in Port-Bouët to $4.45 \pm 0.75 \mu\text{g}/100 \text{ g}$ in Abobo and differed significantly between the two localities ($p < 0.05$).

Table 4: Heavy metal composition of smoke-dried beef skin

Heavy metals ($\mu\text{g}/100 \text{ g}$)	Port-Bouët	Abobo
Cadmium	01.71 ± 0.07^a	01.32 ± 0.07^a
Lead	03.48 ± 0.50^b	04.45 ± 0.75^a
Mercury	ND	ND

Mean $\pm$ Standard deviation ($n = 5$). Values in the same row affected by the same letter are not significantly different ($p > 0.05$) from each other according to Student's *t*-test. ND: Not detected

IV. Discussion

The results of the study revealed that individuals aged between 21 and 35 are the most numerous in this activity. This age group represents a significant part of the Ivorian population, described as young. Historically, this youth traditionally lived in the rural world as active in the agricultural sector. However, the difficulties inherent in this sector have fueled the exodus to large cities. Consequently, the mismatch between vocational training and the labor market explains the difficult access to employment. This situation thus exposes young people to unemployment and drives them toward the informal sector in search of social well-being and financial independence from their parents (INS, 2015; Romaric, 2024). Faced with underemployment and barriers to entering the formal market, the urban informal economy thus stands out as the main refuge for this segment of the active population (Koffi *et al.*, 2023). In this activity, men are the only ones involved in smoking beef skins, and the majority are non-nationals. Moreover, this predominance of the male gender and foreign labor is explained by their strong propensity to emigrate to new horizons in search of economic opportunities and social well-being (IOM, 2017). Regarding logistics, the supply method is unique and largely depends on the slaughterhouses of their communes, where the cost of fresh skin proves favorable. On the financial front, the daily income of these smokers is mostly below 5,000 CFA francs, followed by the bracket between 5,000 CFA francs and 10,000 CFA francs. This corresponds to an estimated monthly earning between 100,000 CFA francs and 150,000 CFA francs. Therefore, in view of these incomes, this activity holds undeniable economic interest, enabling these actors to provide for their needs and those of their families.

On a technical level, the study highlighted two types of treatments: direct smoking, which consists of cutting the skins into pieces and exposing them directly to fire to remove the hair. The second is indirect smoking, which involves prior soaking in warm water, knife peeling, cutting, and then smoking. Therefore, these processes serve both for cleaning and for the proper preservation of smoked skins (Kouassi *et al.*, 2021). As for inputs, the fuel used combines either wood and beef bones, or wood and dry rubbers. These materials are chosen primarily for their availability and low cost, although operators may ignore the toxicological risks incurred by themselves and consumers. For storage and preservation, the use of metal drums and bags is preferred (Adou *et al.*, 2020). Downstream of the sector, in terms of consumption, smoke-dried beef skin ("kplô") is very popular in Côte d'Ivoire, driven by cultural and financial preferences. Indeed, it is mainly integrated into culinary preparations such as seed sauce and okra sauce. Moreover, the latter particularly accompanies the popular dish of the population called "Placali" (Kouamé *et al.*, 2022). Regarding biochemical composition, the moisture content of smoked beef skin is between 42.02% and 42.03%. These values are substantially similar and much lower than those reported by Bousset *et al.* (1986) regarding fresh beef, which range between 71.6% and 77.2%. Furthermore, this low moisture content is explained by the post-mortem pH of meat, which drops from a value close to 7.0 to about 5.5–5.7 within 48 hours in cattle (Cartier and Moëvi, 2007). Products are thus characterized by a normal pale color and a low water-holding capacity. Indeed, the drop in pH reduces the water-binding capacity of muscle and skin proteins during the conversion of muscle into meat (Huff-Loneragan, 2005). Also, the accumulation of lactic acid and the modification of the net protein charge are accompanied by a tightening of the myofibrillar network that expels free water, subsequently facilitating its drastic evaporation during thermal treatment by smoking (Pearce *et al.*, 2011). Nevertheless, moisture content alone is insufficient to establish microbiological stability; water activity and microbiological analyses would be required to support such a conclusion. Conversely, meat products constitute a major source of protein. However, the crude protein content of smoked beef skin, ranging between 36.99% and 45.41%, remains lower than the proportions of 50% to 80% reported by Williamson *et al.* (2005) for beef meat. This variation is explained by technological processing methods, the breed, age, or sex of the animal, and farming conditions directly influencing biochemical quality and amino acid composition (Williamson *et al.*, 2005). Indeed, the heterogeneity of protein profiles observed between skin and muscle tissues stems from physiological modifications linked to ontogenic development and the specific genetic characteristics of each type of livestock (Sakowski *et al.*, 2022). Moreover, structural variations in the collagen matrix and integumentary proteins during animal growth lead to clear fluctuations in the overall nitrogen concentration of processed products (Michalchenko *et al.*, 2024). Regarding lipids, the observed contents between 1.69% and 3.02% are lower than the average of 6% noted by Bauchart *et al.* (2008) for beef meat. In ruminants, the increase in intramuscular lipids

heavily depends on an energy-rich diet (concentrates). This practice generates triglycerides rich in saturated and monounsaturated fatty acids (Sauvant, 2001). Conversely, a grass-based diet favors α -linolenic acid (omega-3) and its derivatives (Dufey, 2010). This dietary orientation thus profoundly modifies the ratio between polyunsaturated and saturated fatty acids within tissues (De Palo *et al.*, 2020). The nature of ingested rations directly influences ruminal bio-hydrogenation and the tissue incorporation of lipids. This confirms the decisive role of farming systems on the final nutritional quality of meat and integumentary products (Noci *et al.*, 2011). These lipid variations are globally linked to species, breed, and diet (Cliquant *et al.*, 2000). The proportion of crude fibers, which is very low (0.03% to 0.06%), agrees with scientific literature stipulating that animal muscle and integumentary tissues do not contain plant dietary fibers (Geay *et al.*, 2001). Consequently, the absence of cellulosic or lignified fractions inherent to the biological structure of tissues of animal origin confirms the specificity of their biochemical profile devoid of complex non-digestible carbohydrates (Lawrie and Ledward, 2006). Similarly, ash rates, ranging between 2.36% and 2.53%, reflect the mineral richness of the animal's diet (Geay *et al.*, 2001) and prove to be higher than those reported by Auvergne (1992) on duck fillets (1.1% to 1.2%). Moreover, this high mineral concentration in integumentary by-products reflects the high density of mineral salts and skeletal or matrix structures associated with the skin of ruminants (Vestergaard *et al.*, 2007). Regarding specific macronutrients, for amino acids, the study confirms the presence of essential amino acids (lysine: 3.90 to 4.48 mg/g DM; leucine: 2.47 to 3.76 mg/g DM; histidine: 1.50 to 1.52 mg/g DM). Nevertheless, these values, lower than those of the reference egg, attest to the protein quality of the product. According to Williamson *et al.* (2005), the nutritional value of proteins is measured by their essential amino acid profile. The latter are capable of covering a significant share of the body's needs for tissue renewal. Indeed, the evaluation of the bioavailability of these amino acids and chemical quality indices confirms that by-products of animal origin possess highly digestible polypeptide structures (Toldrá and Reig, 2011). The high phosphorus and potassium contents corroborate the observations of Jamrozik *et al.* (2000). They confirm that meat products constitute excellent sources of macroelements relative to their energy intake. On the other hand, the relative poverty in trace elements such as manganese aligns with the profiles of beef meat. In this perspective, mineral variability closely depends on genotype and the nutritional inputs of breeding (Bauchart *et al.*, 2008). Furthermore, the analysis of mineral profiles faithfully reflects tissue homeostasis and the geo-pedological conditions of origin of the animals (Suttle, 2010). On the sanitary plane, the detected presence of cadmium and lead in smoked beef skins reflects environmental and trophic contamination (Koffi *et al.*, 2014). This pollution is mainly of exogenous origin, linked to contaminated agricultural soils or the use of inputs and by-products from the trophic chain (Claire *et al.*, 2005). The absence of mercury is explained by the fact that terrestrial meat products do not constitute major vectors of mercury bioaccumulation (Koffi *et al.*, 2014). Significant variations in lead contents are explained by the physico-chemical properties governing its absorption and tissue accumulation (Boudou, 2004). Furthermore, the persistence of these metallic micropollutants in smoked products can also be exacerbated by combustion smoke deposits and the environment of informal processing areas (Aweto *et al.*, 2021). From a toxicological and regulatory standpoint, Commission Regulation (EU) 2023/915, which repealed Regulation (EC) No. 1881/2006, provides current European maximum levels for several contaminants in foods. However, direct regulatory classification of processed smoke-dried bovine skin requires caution because maximum levels depend on the food category and, for processed foods, on concentration or processing factors. Therefore, the present cadmium and lead results are best interpreted as occurrence data rather than as a definitive regulatory compliance assessment. For cadmium, EFSA established a tolerable weekly intake of 2.5 $\mu\text{g/kg}$ body weight. For lead, EFSA concluded that the former provisional tolerable weekly intake was no longer appropriate and did not establish a new health-based guidance value because a clear threshold for adverse effects could not be identified. Consequently, a simple hazard quotient based on an outdated tolerable daily intake for lead should not be used to claim absence of health risk. The relatively low measured concentrations are reassuring, but cumulative dietary exposure and other contaminants generated during smoking should also be considered.

V. Conclusion

This study shows that smoke-dried beef skin ("kplô") marketed in Abidjan contains appreciable amounts of protein, amino acids, and minerals, with compositional differences between samples from Port-Bouët and Abobo. Cadmium and lead were detected at low concentrations, whereas mercury was not detected under the analytical conditions used. These findings provide information on the occurrence of the selected metals but do not, by themselves, establish the overall sanitary safety of the product. This is particularly important because the survey revealed the use of wood combined with dry rubber residues by some processors, a practice that may introduce other hazardous compounds not measured in the present study. Production conditions should therefore be improved by promoting hygienic handling and the exclusive use of appropriate wood fuels. Future studies should include water activity, microbiological quality, and smoking-related contaminants, particularly polycyclic aromatic hydrocarbons (PAHs), including benzo[a]pyrene and PAH4, to provide a more comprehensive assessment of consumer safety.

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