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# Detection of Polycyclic Aromatic Hydrocarbons in Hide and Skin of Slaughtered Cattle and Goats in Anambra State, Nigeria

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## HIGHLIGHTS

- Singeing increase the level of Polycyclic Aromatic Hydrocarbons (PAHs) in hide and skin of slaughtered animals.
- The well-known carcinogenic PAHs in the singed hides and skin were below the maximum permissible limit.
- PAHs of hide and skin are of health concern due to the associated risk on cumulative exposure via dietary use in Nigeria.

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***Acronyms and abbreviations***
GC=Gas Chromatography
PAH=Polycyclic Aromatic Hydrocarbon

## ABSTRACT

**Background:** Polycyclic Aromatic Hydrocarbons (PAHs) are among hazardous chemicals that may endanger food safety. In Nigeria, hides and skins of animals are edible and used in dishes. So, this study investigated the levels of PAHs in singed and unsinged hides and skins of animals slaughtered at three districts abattoirs (Obosi, Uga, and Kwata) in Anambra State, Nigeria.
**Methods:** Using gas chromatography, the levels of PAHs were determined in 120 samples of raw and singed cattle hides and goat skins. Data were analyzed using the SPSS Windows software package (version 20.0).
**Results:** The total PAHs of raw and singed cattle hides were respectively 0.80 and 12.33 µg/kg for Obosi district, 0.56 and 6.96 µg/kg for Uga district, and 8.30 and 16.24 µg/kg for Kwata district. Furthermore, the total PAHs levels in raw and singed goat skins were respectively 2.75 and 9.00 µg/kg for Obosi district, 1.76 and 6.42 µg/kg for Uga district, and 1.30 and 5.19 µg/kg for Kwata district. The levels of some PAHs in singed hides and skins were significantly ($p<0.05$) higher than the unsinged samples.
**Conclusion:** The materials used in singeing may increase the concentration of PAHs in singed hide and skin. Although, the known carcinogenic PAHs in the samples were below the maximum permissible level, it is probably of public health concern due to the associated health risk on cumulative exposure via the dietary consumption of such contaminated local meals.



## Introduction

Polycyclic Aromatic Hydrocarbons (PAHs) are naturally released in the air in form of pollution such as forest fires and volcanoes as well as by human activities like burning and roasting of meat in the abattoirs. These

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chemical compounds are usually deposited on food products especially the smoked and roasted diets as a result of incomplete combustion of hydrocarbons (Palm et al., 2011; Tongo et al., 2017). As much as 200 μg/kg of individual PAHs has been found in smoked fish (Codex Alementarrius, 2007). However, consumption of smoked fish (Adeyeye et al., 2016), meat (Chen et al., 2014), and other meat product (Li et al., 2016; Nisha et al., 2015; Singh et al., 2016) have been implicated in the PAHs accumulation in humans with a calculated mean daily intake of carcinogenic PAHs, including B(a)P and PAH4 at 50 and 276 ng/person, respectively (Abramsson-Zetterberg et al., 2014).

In most animal abattoirs of Nigeria, the singeing practice of hide and skin is done to remove the hair and tenderize it. Therefore, this process may act a predisposing factor for PAHs accumulation in hide and skin of animals as they have been reported in other kinds of roasted foods, including fish, maize, plantain, and cocoyam (Ehigiamusoe et al., 2015; Ofomata et al., 2019; Olabemiwo, 2013; Tongo et al., 2017). The PAHs can enter the human food chain and contaminate processed food which may result in biochemical disruptions of DNA and cell damage in the body (Adam et al., 2013). These chemicals can equally lead to mutations and development of tumors and cancerous cell (Nisha et al., 2015). Thus, a number of PAHs have been found to be carcinogenic and mutagenic in mans (Wenzl et al., 2006).

Although hide and skin are mainly used in leather production in most countries, singed hides (Pomo) are delicacies in many homes and eateries in Nigeria. They are used to prepare soup in homes. In eateries, singed hides are used in making savoury local dishes like Nkwobi, Ngwongwo, Isiewu, etc. In other West African countries such as Ghana and Caribbeans, the animal hides are important ingredients of stews and soups (Akpambang et al., 2009; Akwetey et al., 2013).

High cost of firewood make butchers to jettison the traditionally use of firewood as fuel for singeing meat and resort to the use of scrapped car tyres among others as alternative fuel in many developing countries like Nigeria (Obiri-Danso et al., 2008). In Europe, a maximum level of 12 μg/kg sets for four specific PAHs in meats, including benzo[a]pyrene (BaP), benz[a]anthracene (BaA), benzo[b]fluoranthene (BbF), and chrysene (Chry) (European Commission, 2011). Also, the United States Environmental Protection Agency (EPA, 1998) prioritizes 16 out of about 100 characterized PAHs as pollutants of high toxicity. However, there is no standard regulation and national program for routine monitoring of PAHs in food in Nigeria (Plaza-Bolanos et al., 2010). This study aimed at determining the materials used for singeing and the levels of PAHs in singed and unsinged hides and skin of slaughtered animals in Anambra State, Nigeria.

**Materials and methods**

*Study area*

The study was conducted in Anambra State, Nigeria which is situated between latitudes $5^0$ 22’ and $6^0$ 45’; and longitude $6^0$ 43’ and $7^0$ 22’ E sharing boundaries with Kogi and Enugu in the North, Imo and Abia in the East, Rivers in the South and Delta and Edo states in the West. It has a total land area of 4 416 sq. km with a human population of about 4 805 600 (National Population Commission of Nigeria, 2011). For this study, three abattoirs (Obosi, Kwata, Uga) were selected due to having the highest slaughter activities from each of the three senatorial districts of the state (Anambra Central, North and South) as illustrated in Figure 1.

*Samples*

In this cross-sectional survey, systematic random sampling (one in five) was used to select 10 each for cattle hide and goat skin in the selected abattoirs. A total of 120 post-slaughter samples comprising of hide and skin before singeing and after singing were collected between May to October 2019. The sample size in all four groups was equal (n=30). Five g of each sample was cut for subsequent PAHs analysis with Gas Chromatography (GC).

*GC analysis*

The samples were grounded with sodium sulphate as drying agent to fine consistency. Extraction of PAHs was done as described by Pena et al. (2006) and Ofomata et al. (2019). The extracts were analyzed for naphtha-lene, acenaphthylene, benzo[b]fluoranthene, phenanthrene, dibenzo[a,h]anthracene, chrysene, benzo[a]pyrene, acenaphthene, benzo[k]fluoranthene, fluorene, pyrene, benzo[a]anthracene, anthracene, fluoranthene, indeno [1,2,3-cd]pyrene, and benzo[g,h,i]perylene. Corresponding results were obtained using GC (Agilent 5890N, Hewlett-Packard HP-5890 Series II, USA) with Flame Ionization Detection (FID). The GC was programmed as follows: initial temperature of 60 $^{\circ}$C for 2 min and ramped at 25 $^{\circ}$C/min to 300 $^{\circ}$C for 5 min and allowed to stay for 15 min giving a total run time of 22 min. A 2 L volume split less injection mode was used and the injection port temperature was set at 250 $^{\circ}$C, while 300 $^{\circ}$C was maintained for the injection port of the FID detector (Jira et al., 2008; Nnaji et al., 2017). A standard mixture of 17 priority PAHs, including naphtha-lene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[b] fluoranthene, indeno(1,2,3)perylene, dibenzo[a,h] anthracene, and benzo[g,h,i]perylene was obtained and



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used for the analysis. Compounds were identified by comparing the retention time of standards with that obtained from the extracts while the individual analysis of PAHs were used for quantification. Naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene were assessed as non-carcinogenic PAHs, while benzo[a]anthracene, chrysene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[b] fluoranthene, indeno(1,2,3)pery-lene, dibenzo[a,h] anthracene, and benzo[g,h,i]perylene were the determined as carcinogenic PAHs (EPA, 1998).

*Data analysis*

Data were analyzed using SPSS software package (version 20.0). Student t-test was used to determine the difference in mean concentrations of PAHs in unsinged and singed hides, as well as skin and different heat sources. Significance level was considered at *p*<0.05.

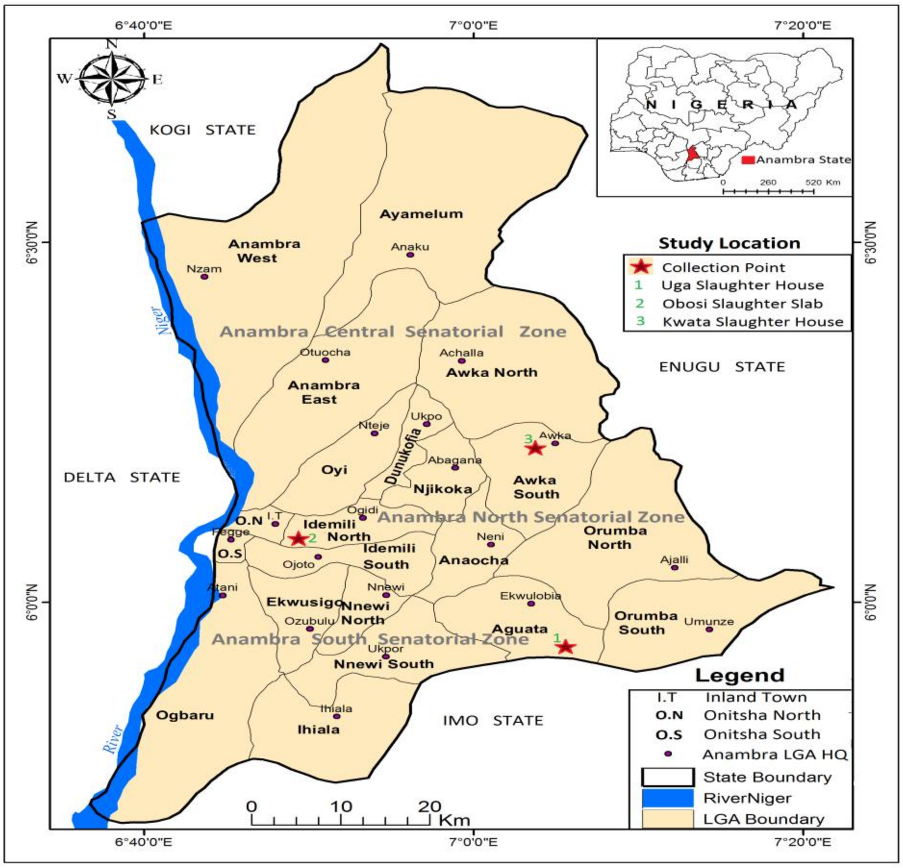


**Figure 1:** Map of Anambra State showing samples collection points

## Results

It was discovered that butchers used palm kernel shells for singeing at Uga abattoir, scrap tyres fueled with kerosene at Obosi abattoir, and soft wood (bamboo wood) fueled with animal fats and kerosene at Kwata abattoir. Different level of PAHs accumulations were observed in unsinged cattle hides and goat skins at different locations which were increased after singeing. However, none of the samples exceeded the maximum permissible levels of 12 and 2 µg/kg for the carcinogenic PAH4 and benzo[a]pyrene, respectively.



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*Obosi abattoir*

At Obosi abattoir, the four members of the 'PAH4' and B[a]P were detected in unsinged hides, with a total of 0.33±0.3516 and 0.1003 µg/kg, respectively which increased to 3.65±3.8737 and 1.33±0.6507 µg/kg after singeing in that order. The total PAHs in unsinged hides was 0.80±0.7385 µg/kg which was increased to 12.33±8.8699 µg/kg after singeing. There were significant difference (*p*<0.05) between the singed and unsinged hides in the levels of PAHs components, including benz[a]anthracene, benzo[b]fluoranthene, chrysene, and xylene as indicated in Table 1.

Furthermore, the mean concentrations of PAH4 and B[a]P in unsinged skins increased after singeing in that order. The total PAHs in unsinged and singed skins were 2.75±1.7275 and 9.00±9.6324 µg/kg, respectively. Benz[a]anthracene and benzo[b]fluoranthene showed significant difference (*p*<0.05) in their mean concentrations in unsinged and singed skins (Table 2).

*Kwata abattoir*

At Kwata abattoir, the four members of the PAH4 were detected in unsinged hides at a total concentration level of 1.30±1.305 µg/kg, while B[a]P was at 0.63±0.7322 µg/kg which increased to 3.48±2.0244 and 0.96±0.6376 µg/kg, respectively after singeing. The total PAHs in both unsinged and singed hides were 8.3±7.3872 and 16.24±14.7557 µg/kg, respectively. There were significant differences (*p*<0.05) in mean concentrations between the singed and unsinged hides from the PAHs components including benzo[b]fluoranthene, chrysene and 1,2-benzanthracene (Table 3).

The mean concentrations of PAH4 and B[a]P in unsinged skin were 0.84±1.1015 and 0.04±0.0415 µg/kg, respectively which increased to 2.9±2.2149 and 0.05±0.0404 µg/kg in the same order, after singeing. The total PAHs recorded in the unsinged and singed skins were 1.35±1.8768 and 5.19±5.2032 µg/kg, respectively. There was significant difference (*p*<0.05) in mean concentration of benzo[a]pyrene and chrysene between unsinged and singed skin (Table 4).

*Uga abattoir*

At Uga abattoir, the PAH4 as well as B[a]P mean concentrations in unsinged hides were 2.92±0.4534 and 0.31±0.0350 µg/kg, respectively which increased to 4.38±2.2329 and 0.71±1.1231 µg/kg after singeing in the same order. The total PAHs recorded in unsinged and singed hides were 0.56±0.6487 and 6.96±7.774 µg/kg, respectively. There were significant differences (*p*<0.05) between the mean concentrations of PAHs in unsinged and singed hides in these PAHs components including benz[a]anthracene, benzo[b]fluoranthene, benzo[a]pyrene and chrysene (Table 5).

The PAH4 and B[a]P mean concentrations in unsinged skin were 1.41±1.8442 and 0.36±0.2645 µg/kg, respectively which increased to 4.30±3.0421 and 0.50±0.4585 µg/kg respectively, after singeing. The total PAHs recorded in unsinged and singed skins were 1.76±2.3667 and 6.42±5.6161 µg/kg, respectively. There was significant difference (*p*<0.05) in the mean concentration of benzo[a]pyrene in unsinged and singed skin (Table 6).

**Table 1:** Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg) in unsinged and singed cattle hides at Obosi abattoir, Anambra State, Nigeria

| PAHs | Unsinged hide | Singed hide | t-value | *P*-value | %Increase |
|---|---|---|---|---|---|
| Naphthalene | 0.0801 | 0.1780±0.0616 | 0.03 | 0.97 | 55.0 |
| Anthracene | 0.0201±0.0000 | 2.5420±0.9323 | -2.31 | 0.15 | 99.21 |
| Benz[a]anthracene | 0.0404±0.0575 | 0.9560±1.6078 | -2.98 | 0.03 | 95.8 |
| Benzo[b]fluoranthene | 0.1702±0.2870 | 0.2098±0.3143 | -2.54 | 0.03 | 18.9 |
| Benzo[k]fluoranthene | 0.0547±0.0427 | 0.1782±0.3109 | -0.77 | 0.46 | 69.3 |
| Benzo[g,i,h]perylene | 0.0382±0.0349 | 2.3428±0.3900 | -1.72 | 0.12 | 98.37 |
| Benzo[a]pyrene | 0.1003 | 1.3315±0.6507 | -2.36 | 0.25 | 92.5 |
| Chrysene | 0.0159±0.0071 | 1.1543±1.3009 | -4.4 | 0.04 | 98.6 |
| Fluoranthene | 0.0235±0.0207 | 1.9560±1.6078 | -1.41 | 0.19 | 98.8 |
| Pyrene | 0.0941±0.1172 | 0.2098±0.3143 | -0.77 | 0.46 | 55.2 |
| 1,2-Benzanthracene | 0.1335±0.1474 | 1.1543±1.3009 | -1.32 | 0.24 | 88.4 |
| Xylene | 0.0282±0.0240 | 0.1203±0.0784 | -2.52 | 0.03 | 76.6 |



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**Table 2:** Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg) in unsinged and singed goat skins at Obosi abattoir, Anambra State, Nigeria

| PAHs | Unsinged skin | Singed skin | t-value | *P*-value | %Increase |
|---|---|---|---|---|---|
| Naphthalene | 0.0602 | 0.0904 | | | 97.4 |
| Acenaphthene | 0.0602 | 0.5307 | | | 88.7 |
| Anthracene | 0.0603±0.0529 | 0.2930±0.9038 | -1.09 | 0.32 | 79.42 |
| Benz[a]anthracene | 0.3783±0.4231 | 0.9252±1.0286 | -2.51 | 0.04 | 59.1 |
| Benzo[b]fluoranthene | 0.6514±0.3646 | 0.8165±0.8948 | -2.75 | 0.02 | 20.2 |
| Benzo[k]fluoranthene | 0.1001 | 0.2003 | | | 50.0 |
| Benzo[g,i,h]perylene | 0.1542±0.2065 | 1.0426±1.4450 | -0.81 | 0.46 | 85.2 |
| Benzo[a]pyrene | 0.7003±0.1412 | 1.9517±1.0397 | -1.60 | 0.21 | 64.1 |
| Chrysene | 0.0752±0.0211 | 0.2930±0.9038 | -2.25 | 0.07 | 74.33 |
| Diaben(a,h)anthracene | 0.0457±0.0487 | 0.9252±1.0286 | -1.13 | 0.31 | 95.1 |
| Fluorene | 0.0252±0.0320 | 0.0965±0.2596 | -2.07 | 0.06 | 73.89 |
| Phenanthrene | 0.0752±0.0211 | 0.6119±0.7734 | -0.93 | 0.38 | 87.7 |
| Pyrene | 0.0602±0.0424 | 0.7492±0.8565 | -1.08 | 0.31 | 92.0 |
| 1,2-Benzanthracene | 0.0611±0.0439 | 0.1595±0.0234 | -0.95 | 0.37 | 61.69 |
| Xylene | 0.2453±0.3724 | 0.3086±0.4752 | -1.11 | 0.3 | 20.51 |

**Table 3:** Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg) in unsinged and singed cattle hides at Kwata abattoir, Anambra State, Nigeria

| PAHs | Unsinged hide | Singed hide | t-value | *P*-value | %Increase |
|---|---|---|---|---|---|
| Naphthalene | 0.3436±0.4286 | 0.6318±0.7322 | -0.71 | 0.5 | 45.6 |
| Acenaphthylene | 0.4948±0.4470 | 1.3815±1.5732 | -0.93 | 0.4 | 64.2 |
| Anthracene | 0.5691±0.7159 | 1.4843±1.4334 | -1.62 | 0.13 | 61.7 |
| Benz[a]anthracene | 0.0239±0.0343 | 0.8009±0.2829 | -1.82 | 0.11 | 97.0 |
| Benzo[b]fluoranthene | 0.1426±0.1269 | 0.9009±0.0005 | -2.71 | 0.03 | 84.2 |
| Benzo[k]fluoranthene | 1.1322±0.8278 | 1.8341±1.6313 | -0.78 | 0.46 | 38.3 |
| Benzo[g,i,h]perylene | 1.0427±1.3714 | 1.6793±2.1230 | -0.37 | 0.74 | 37.9 |
| Benzo[a]pyrene | 0.6318±0.7322 | 0.9625±0.6376 | -1.45 | 0.19 | 34.4 |
| Chrysene | 0.5040±0.4116 | 0.8152±1.1034 | -2.34 | 0.04 | 38.2 |
| Diben[a,h]anthracene | 1.0049±0.1871 | 1.0337±1.0068 | -0.05 | 0.96 | 2.8 |
| Fluorene | 0.3371±0.4901 | 0.8765±0.6943 | -1.48 | 0.17 | 61.5 |
| Indeo[1,2,3,cd]pyrene | 0.8152±0.0001 | 0.9008±1.1034 | 0.10 | 0.92 | 1.8 |
| Pyrene | 1.0316±1.1795 | 1.2281±1.5253 | 0.20 | 0.84 | 16.0 |
| 1,2-Benzanthracene | 0.0397±0.0278 | 1.0302±0.0364 | -37.48 | 0.00 | 96.1 |
| Xylene | 0.3003±0.4069 | 0.6842±0.8720 | -0.83 | 0.43 | 56.1 |

**Table 4:** Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg) in unsinged and singed goat skins at Kwata abattoir, Anambra State, Nigeria

| PAHs | Unsinged skin | Singed skin | t-value | *P*-value | %Increase |
|---|---|---|---|---|---|
| Naphthalene | 0.0538±0.0404 | 0.3032±0.3322 | -1.81 | 0.09 | 82.3 |
| Benz[a]anthracene | 0.1240±0.3088 | 0.3032±0.3322 | 0.30 | 0.77 | 59.1 |
| Benzo[b]fluoranthene | 0.5019±0.4341 | 0.8743±1.0248 | -1.98 | 0.07 | 42.6 |
| Benzo[k]fluoranthene | 0.3279±0.5828 | 0.8697±0.7882 | -1.14 | 0.29 | 62.3 |
| Benzo[g,i,h]perylene | 0.0514±0.0371 | 0.2948±0.4042 | -1.01 | 0.35 | 82.7 |
| Benzo[a]pyrene | 0.0352±0.0415 | 0.0538±0.0404 | -3.11 | 0.01 | 34.6 |
| Chrysene | 0.1789±0.3171 | 1.7124±0.8175 | -3.53 | 0.01 | 89.6 |
| Phenanthrene | 0.0564±0.0979 | 0.2467±0.4147 | -0.89 | 0.4 | 77.1 |
| Pyrene | 0.0118±0.0052 | 0.2321±0.3880 | -0.96 | 0.38 | 94.9 |
| 1,2-Benzanthracene | 0.0107±0.0119 | 0.2971±0.6610 | -1.22 | 0.24 | 96.4 |


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**Table 5:** Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg) in unsinged and singed cattle hides at Uga abattoir, Anambra State, Nigeria

| PAHs | Unsinged hide | Singed hide | t-value | *P*-value | %Increase |
|---|---|---|---|---|---|
| Naphthalene | 0.0468±0.0305 | 0.3210±0.4212 | -1.12 | 0.32 | 85.4 |
| Acenaphthene | 0.0337±0.0373 | 0.0461±0.0451 | -0.33 | 0.76 | 26.9 |
| Acenaphthylene | 0.0296±0.0222 | 0.1700±0.2682 | -1.37 | 0.19 | 82.6 |
| Anthracene | 0.0602 | 0.7077±1.1231 | -0.49 | 0.67 | 91.5 |
| Benz[a]anthracene | 0.0123±0.0143 | 0.9456±0.0833 | -2.65 | 0.03 | 98.7 |
| Benzo[b]fluoranthene | 0.0282±0.0153 | 0.9456±0.0833 | -2.70 | 0.02 | 96.2 |
| Benzo[k]fluoranthene | 0.0303±0.0144 | 0.6838±0.5157 | -1.70 | 0.19 | 95.6 |
| Benzo[a]pyrene | 0.0307±0.0350 | 0.7077±1.1231 | -3.22 | 0.01 | 95.7 |
| Chrysene | 0.2204±0.3888 | 1.7842±0.9432 | -3.08 | 0.02 | 87.7 |
| Fluorene | 0.0191±0.0224 | 0.7077±1.1231 | -1.18 | 0.26 | 88.0 |
| Indeo[1,2,3,cd]pyrene | 0.0082 | 1.7842±0.9432 | -0.50 | 0.64 | 95.8 |
| Pyrene | 0.0068±0.0033 | 0.0567±0.0393 | -2.12 | 0.07 | 88.0 |
| 1,2-Benzanthracene | 0.0411±0.0479 | 0.5172±0.9905 | -0.96 | 0.37 | 92.1 |
| Xylene | 0.0226±0.0173 | 0.0763±0.0808 | -1.29 | 0.29 | 70.2 |

**Table 6:** Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg) in unsinged and singed goat skins at Uga abattoir, Anambra State, Nigeria

| PAHs | Unsinged skin | Singed skin | t-value | *P*-value | %Increase |
|---|---|---|---|---|---|
| Naphthalene | 0.0155±0.0190 | 0.1751±0.3688 | -1.05 | 0.31 | 91.2 |
| Anthracene | 0.0305±0.0372 | 0.0985±0.1353 | -1.08 | 0.30 | 69.0 |
| Benz[a]anthracene | 0.4660±0.7507 | 0.5460±0.7797 | -1.87 | 0.09 | 14.7 |
| Benzo[b]fluoranthene | 0.5460±0.7797 | 1.4613±0.4846 | -2.23 | 0.05 | 62.6 |
| Benzo[g,i,h]perylene | 0.0728±0.0722 | 0.3610±0.3956 | -1.75 | 0.11 | 79.8 |
| Benzo[a]pyrene | 0.3592±0.2645 | 0.5015±0.4585 | -4.2 | 0.01 | 28.4 |
| Chrysene | 0.0351±0.0493 | 1.7955±1.3193 | -1.11 | 0.3 | 98.1 |
| Fluoranthene | 0.0430±0.0471 | 0.3031±0.4681 | -1.11 | 0.31 | 85.8 |
| Fluorene | 0.0474±0.0480 | 0.4771±0.4752 | -1.52 | 0.19 | 90.1 |
| Pyrene | 0.1741±0.2909 | 0.4069±0.3392 | 0.88 | 0.40 | 39.6 |
| Xylene | 0.0132±0.0081 | 0.2905±0.3918 | -1.72 | 0.11 | 95.5 |

## Discussion

The results from this study showed that unsinged cattle hide and goat skins from three abattoirs in three senatorial districts of Anambra State, Nigeria contained varying degrees of PAHs which increased in concentration after singeing. Increase in concentration of PAHS was also reported in smoked fish (Adeyeye et al., 2016), meat (Chen et al., 2014), and other meat product (Li et al., 2016; Nisha et al., 2015; Singh et al., 2016). The concentration of PAHs in the raw hides and skins in the present survey may be attributed to accidental or unintentional exposure to PAHs during grazing of the animals or industrial exposure due to air pollution (Hussein and Mona, 2016). This is exacerbated by the extensive system of cattle and goats production in the state in which the animals are exposed to the contaminated air and grazing field (Ofomata et al., 2019). In addition, burning of bush and waste which are common practice in Nigeria, releases smoke into the atmosphere which precipitates as dew in the morning. Given that livestock are rarely housed but left over night in the open field in Nigeria, the dew fall on the body of the animals with the resultant penetration of PAHs into their skin (Okonkwo et al., 2014). According to Erema and Adaobi (2013), PAHs can enter the body through inhalation, ingestion and contact. However, dietary intake is reported as the major route of human and animal exposure to PAHs (Xia et al., 2010).

The accumulation of PAHs levels in raw meat is also dependent on some topographical factors and the season. In dry season, there is increased risk of exposure to PAHs from chemicals and contaminated feeds as animals scavenge for feed and water (Abou-Arab et al., 2014). In the current work conducted during the rainy season, lower level of PAHs component were detected compared to the previous study in dry season in Nigeria conducted by Ofomata et al. (2019). A seasonal trend of PAH16 in the water from Lake Chaohu, China has been reported with an average residual level of 70.8 ng/l in the water (Qin et al., 2014). Our findings agreed with that of Odiba and

Chukwuma (2017) in Northern Nigeria and Ofomata et al. (2019) in Eastern Nigeria who observed appreciable amount of PAHs in raw hides and skin including benzo[a]pyrene, benz[a]anthracene, benzo[b]fluoranthene, chrysene, and xylene.

In the present study which covers three senatorial district of Anambra State, Nigeria, PAHs levels were higher than what was reported previously in Awka, Nigeria (Ofomata et al., 2019). The findings of the present study also differ from the results indicated by Ogbonna and Nwaocha, (2015) in Umuahia, Abia State, Nigeria where most PAHs in the singed cow hide were below GC detection limit. The sample size, sample source, as well as the level of environmental pollution may be responsible for the rates of PAHs components detection in the different studies.

The PAH4 level in the unsinged hide and skin were below the maximum permissible limit of 12 µg/kg compared to the 57.23 µg/kg reported in smoked meats in Abidjan, Cote d'Ivoire where the permissible level was exceeded (Manda et al., 2012). On the other hand, the total PAHs in our samples were higher than 2.611 µg/kg reported in beef meat sample from different locations in Greater Cairo Urban Region, Egypt (Abou-Arab et al., 2014). Type and intensity of heat source, and its distance from food have also been implicated in the increased accumulation of PAHs in meat (Dike and Adedolapo, 2012; Hussein and Mona, 2016; Okonkwo et al., 2014).

The significant increase in the level of PAHs after singeing in all the sampled hide and skin from three studied abattoirs may be due to the use of different combustible materials for singeing in the study area. According to Ezike et al. (2017), the level of PAHs in the smoked fish in Nigeria varied according to the different heat sources. At Obosi where the butchers' used scrap tyres fueled with kerosene to singe hides and skin, benzo[a]pyrene was determined as 1.33 µg/kg which was lower than those previously found in two other areas of Abia State, Nigeria (Nnaji et al., 2017), including Umuahia (4.80 µg/kg) as well as Okigwe (3.30 µg/kg). However, similar with our result, benzo[a]pyrene level was 1.16 µg/kg in roasted cowhide from Northern Nigeria (Odiba and Chukwuma, 2017).

At Uga area, butchers used palm kernel shells for singeing hides and skin and the total PAH4 recorded in hides and skin were 6.96 µg/kg and 6.42 µg/kg, respectively. Although they were below the maximum permissible limit, they may constitute public health risks. At Kwata abattoir, where soft wood (bamboo wood) fueled with animal fats and kerosene were used for singeing of carcass, high levels of PAHs were recorded. This is in agreement with Ezike et al. (2017) who recorded high levels of PAHs in fish smoked on softwood. This could be attributed to the fact that softwoods have high content of lignin and resin which are known to promote soot and smoke with high concentrations of PAHs when used in singeing (Nollet, 2007). At Kwata abattoir where animal fats which contain PAHs are used in fuelling of wood, the fats melt, drip into the fire and produce more PAHs which are deposited on the meat. Our results from different sample collection points (Obosi, Uga, Kwata) showed that the levels of PAHs were higher in the singed hides than in the singed skin.

## Conclusion

Cattle hide and goat skin samples from abattoirs in the three districts of Anambra State, Nigeria contained different component of PAHs. The materials used in singeing may increase the concentration of PAHs in singed hide and skin. Although the known carcinogenic PAHs in the samples were below the maximum permissible level, it is probably of public health concern due to the associated health risk on cumulative exposure via the dietary consumption of such contaminated local meals. It is necessary to educate butchers on choosing safe meat processing methods in addition to enforcement of food safety legislation regarding PAHs in the country.

## Author contributions

I.B.O., J.A.N., R.I.O., as well as E.V.E. designed the research, and analyzed the data. I.O.N. and A.J.O. wrote and revised the manuscript. I.B.O. conducted the experiment. All authors read and approved the final manuscript.

## Conflicts of interest

All authors declare that there was no conflict of interest regarding the publication of this article.

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