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Research Paper

Contamination Burden and Risk Assessment of Selected Pollutants in Goat Meat Roasted With Rubber Tyre

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Abstract: *Contamination levels of Heavy metals (HMs), Polycyclic Aromatic Hydrocarbons(PAHs) and phthalate esters (PEs) in roasted goat meat was determined.*
Goat meat samples were collected from the abattoir and grouped as roasted-unwashed (RUW), roasted washed (RW) and unroasted ones used as control samples (CS). Samples for HMs were digested with HNO_3: H_2O_2 and determined by Atomic Absorption Spectrophotometer. PAHs and PEs in meat samples were extracted using n-Hexane: Dichloromethane by ultra-sonication. Clean-up was done with C-18 cartridges for PAHs and alumina for Phthalates and determined using Gas Chromatograph with Flame ionization detector. Data were analyzed using mean and standard deviation. Health Risk Assessment was calculated to know the risk posed by these pollutants to consumers.
Mean concentrations of PAHs ranged from 11.57±8.84µg/g in CS samples to 22.80± 10.62µg/g in RUW samples. Benzo (a) pyrene was found only in RUW samples. Concentration of PEs ranged from 1.15µg/g to138.93µg/g. Di-ethylhexylphthalate (DEHP) has the highest concentration of 138.93µg/g in RUW samples. For HMs, Cobalt and Manganese were not detected; Iron concentration had a range of 12.28 µg/g – 49.03µg/g while concentration of Copper and Zinc ranged below 30µg/g. Lead concentration in samples ranged from 0.13 ± 0.1µg/g to 5.09 ± 0.45µg/g. Results of recovery studies shows that DEHP gave a recovery of 86% while Fluorene gave a recovery of 92%. Risk assessment results shows RW meat is safe for consumption. For food safety, security of human health and lives, regulatory authority should take proactive measures in preventing roasting of slaughtered goat with tyres in order to minimize the inherent environmental and health hazards that may be associated.
Keywords: *Roasted, Goat meat, Risk assessment, Pyrene, Polycyclic Aromatic Hydrocarbons (PAHs)*

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I. INTRODUCTION

Goat meat and its hide as a delicacy have distinguished itself as a special dish in homes and ceremonial gatherings in the Middle East and half of the Asian continent. Goats are easier to raise in places that don't have large acreage of rich grasslands than sheep or cattle and they can survive on browse that other animals can't eat. They provide milk that can be made into cheese or yoghurt. The low levels of saturated fat and cholesterol combined with its high iron and protein content make goat meat a good choice for anyone looking for a healthy red meat. It's a leaner, healthier choice when compared to equal serving sizes of chicken, beef and pork.1 Goat meat are usually consumed alongside with the hide unlike cow hides which can be separated from the meat or eaten as a whole. present in air and may leach into food and water packaged into plastics while PAHs are the products of incomplete combustion of organic compounds which may be deposited on food and animal products when been processed for human consumption.

In Nigeria and some other slaughter houses in some parts of the world, goat hides are roasted with rubber tyres after slaughtering. This is due to the high cost of running abattoirs on clean energy fuels and the availability of alternative sources of fuel such as firewood, wood chippings, kerosene, and coal and even scrap rubber tyres. Slaughter houses therefore resort to using these alternative fuels in roasting these animals. The implication of the use of these alternative sources of fuel especially rubber tyres, is the risk of possible contamination of the goat meat with products of combustions of these fuels and in essence exposes the consumer to health related issues resulting from these contaminants. The Michelin digest (2017)[6], reports that a typical rubber tyre is composed of elastomers (Natural and synthetic rubber), reinforcing filers (Carbon black and silica), plasticizers (Aromatic or paraffinic which could be phthalate based, resins or oils), metal and textile reinforcement to provide framework for strong physical-chemical bond between rubber and steel. As a result, roasting goat meat with expired rubber tyres would introduce certain combustion products onto and into the meat. These contaminants include Polycyclic Aromatic Hydrocarbons (PAHs), Phthalates, Heavy Metals and many more.

Concerns have been raised about the effects of some of these compounds on the environment, human reproductive system and function of hormones in the body. This obviously indicates that whatever goes into the animals will eventually get to man as food in relation to food chain. This may pose health risks to human. Seven of the enlisted PAHs investigated have also been implicated to be known carcinogens and endocrine disruptors as classified by the United States Environmental Protection Agency.[7] The International Agency for research on cancer[8] reports that heavy metals affect cellular organelles and components such as cell membrane, mitochondrial, lysosome, endoplasmic reticulum, nuclei and some enzymes involved in metabolism, detoxification and damage repair.

Metal ions have been found to interact with cell components, such as DNA and nuclear proteins, causing DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis. Reports from quantification of PAHs, Phthalates and heavy metals in roasted goat meat hides are scarce in literature. Most studies have been carried out on cow meat but there is paucity of information on contaminants like this in goat meat. This study was therefore aimed at investigating levels of selected phthalate esters, polycyclic aromatic hydrocarbons and heavy metals in roasted and washed goat meat samples, roasted and unwashed goat meat samples while monitoring baseline levels of these compounds in hot water scalded goat meat samples.

Human health risk assessment is a process used to estimate the health effects that might result from exposure to carcinogenic and non-carcinogenic chemicals.[9] Hazard quotient was calculated and index for each group of contaminant was ascertained.

II. MATERIALS AND METHODS

2.1. Sampling Location

The study was conducted using the Lagos State Municipal Abattoir (latitude6°27'11.0002"N and longitude 3°23'44.9999"E) Oko - Oba, Agege, Lagos State, Nigeria. This location was chosen due to the fact that it is the largest abattoir in Nigeria as it slaughters about 2,400 livestock (cattle, goats and camels inclusive) on a daily basis.[10,11] Lagos is also Nigeria's most cosmopolitan city and second most populated after Kano State, with an estimated population of 21 million people.[12]

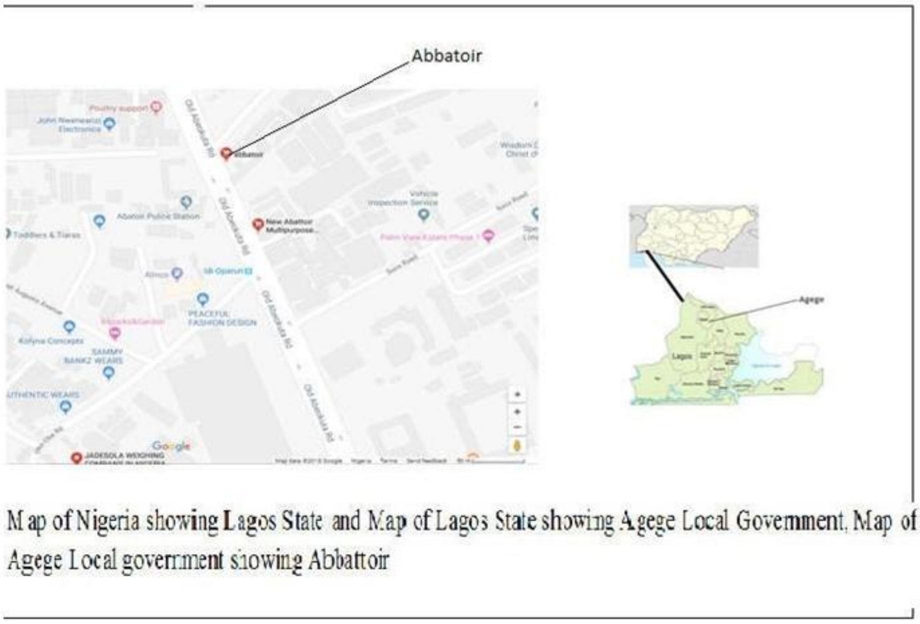

Figure 1: Map showing Agege Local Government of Lagos State, Nigeria

2.2. Process of Roasting: The roasting process was done using expired rubber tyres. The process involves placing the slaughtered goat over a large pile of burning rubber tyres, sometimes, with firewood added. Samples were collected from the thighs and rib regions of each goat meat. These parts were exposed to the burning more and are the choicest part of the meat. Control samples were not burnt; they were scalded with hot water and scrapped with knives. Samples were obtained as goat meat and hide since goat meat is usually consumed as a whole unlike cow hide (ponmo) and its beef which can either be consumed together or separately.

2.3. Sampling: A total of nine **(9) r**andom samples of goat meat were collected from the sample location within a space of four weeks. All samples were collected in cured aluminum foil, wrapped and placed in coolers of ice and then transported to the laboratory and stored in a freezer at -18 ^oC before analysis. Four samples of roasted and washed goat meat and hide (these were collected after the burnt goat had been washed with water to show the potential threat consumers are exposed to), three samples of roasted but unwashed goat meat (samples were obtained from burnt unwashed carcass to give the initial level of contaminants deposited) and two hot water scalded goat meat samples, to serve as control samples, were collected.

2.4. Reagents

Methanol, n-Hexane, and Dichloromethane (all HPLC grade) were obtained from Liposolv, Merck Chemicals. PAHs reference standard containing a mixture of all thirteen PAHs determined in this study was obtained from Sigma-Aldrich Chemicals, Switzerland. Individual standards for Dimethyl Phthalate (DMP), Di ethyl Phthalate (DEP), Di Butyl Phthalate (DiBP) and Di Ethyl Hexyl Phthalate (DEHP) were also obtained from Sigma-Aldrich Chemicals, Switzerland. All standards were of ≥ 99% purity. Nitric Acid, Hydrogen Peroxide and distilled water of at least 18MΩ, purified by Nano ultrapure water system was used for the analysis.

2.5. Experimental

Sample Preparation: Prior to instrumental determination of any analyte, samples were de-boned and blended. Portions of the blended samples were then taken for digestion and extraction processes.

Digestion of samples for Heavy metals: Procedure used by Akoto et al, 2014[13], was adapted.

Approximately 5g of each sample was digested in a mixture of HNO_3 and H_2O_2 (6: 1 v/v) at 60 ^OC until transparent solution appeared. The resulting solution was then allowed to dry to about 2 mL.
Volume of each digest was then adjusted to 100mL using distilled water as diluent and filtered through Whatmann filter papers. These solutions were then stored in pre-cleaned plastic tubes and stored for determination of heavy metals using a Flame Atomic Absorption Spectrophotometer (FAAS).

Extraction of PAHS and Phthalate Esters: Both analytes were simultaneously extracted using approximately 3g of each sample with n-Hexane: Dichloromethane (75:25 v/v %) in an ultrasonic bath set at 42^{O}C, 120Hertz for 30minutes in two successive extractions using 30mL portion of solvent mixture for each extraction. A total of 60 mL extract was obtained for each sample.

Clean-up and Isolation of PAHs: From each 60 mL of extract for each sample, 30mL was quantitatively measured and passed through a 3 mL C-18 SPE cartridge (Silicycle Inc.SPE-R31930B-03G). All cartridges were conditioned with 5mL n-Hexane before loading and PAHs were eluted with 2 mL DCM collected into pre-cleaned and baked glass vials. Each vial was properly capped and labeled and transferred for GC-FID analysis.

Clean-up and Isolation of Phthalates: The remaining 30 mL extract for each of the samples was passed through a column packed with activated alumina. Columns were conditioned with 10mL

Methanol before loading and Phthalates were eluted with 5mL Methanol. Eluate was allowed to evaporate to dryness then reconstituted with 2mL Methanol. The reconstituted solution was transferred into pre-cleaned and baked glass vials, properly capped and labeled for GC-FID analysis.

2.6. Instrumental Analysis: Phthalates and PAHs were determined using an Agilent 7820A Gas Chromatograph with Flame Ionization Detection. Separation involved an HP-55% Phenyl 95%

Methyl Polysiloxane 30m x 320 µm x 0.25µm column. External Standardization was used for generation of calibration curves for each analyte with regression of not less than 0.998 for each of the curves.

2.7. Theory of Risk Assessment: Human health risk assessment is the process of estimating both the probability that an event will occur, and the probable magnitude of its adverse effects -economic, health/safety-related, or ecological—over a specified period of time. The risk assessment process involves four steps: Hazard identification, exposure assessment, dose response assessment and risk characterization. In this study, exposure assessment through the ingestion of contaminated goat meat will be assessed[14]. Hazard identification which is the first step in risk assessment investigates chemicals or other agents present at any given location including their concentration and distribution which can pose threats to the environment or consumers. In the meat samples collected, heavy metals, poly aromatic hydrocarbons and phthalates are possible hazards to consumers.
Exposure assessment measures or estimates the intensity, duration and frequency of human exposure to an environmental agent or contaminant. The exposure route through which the transfer occurs can be via ingestion of water or food, inhalation or absorption through the skin on dermal contact by adults or children. The exposure pathway is a course through which a hazardous agent gets to its receptor. In this study, exposure assessment was carried out by measuring the average daily intake of heavy metals, PAHs and phthalates through ingestion only.
Dose-response assessment estimates capacity of chemicals or other contaminants to cause harm depending on their exposure levels. The two important toxicity indices used are cancer slope factor (which is a carcinogen potency factor, CSF) and reference dose which is a non-carcinogenic threshold (RfD). The RfD value is obtained by dividing the NOAEL (No observable toxic effect) by an appropriate uncertainty factor, sometimes called a safety factor or uncertainty factor. For humans, a 10-fold uncertainty factor is used.

Risk characterization is the final phase of risk assessment. Here, exposure and dose response assessment are integrated to yield probabilities of effects occurring in humans under specific exposure conditions. This helps to arrive at quantitative estimates of cancer risk and hazard indices.

CDI is the index to evaluate human body intake for contaminant via contact. The formula for ingestion is as follows:

$$CDIi = \frac{C \times IR \times ED \times EF}{BW \times AT} \quad (1)$$

Where CDI is the daily intake through ingestion, C represents the concentration of heavy metals (µg/g); IR represents the ingestion rate of the meat sample (30grams/day), EF is the abbreviation of exposure frequency and set at 365days/year, ED means exposure duration and the value is 70 years, Body weight was abbreviated as BW (60kg) and AT means Averaging Time (25,550 days).

HQ indices for Heavy Metals: The potential non-carcinogenic risk for heavy metals is

expressed by Hazard Quotient (HQ) for a single substance and Hazard Index (HI) for multiple

substances and/or exposure pathways. Unlike a carcinogen, the toxicity is important only during the time of exposure, which may be one day, a few days, or years. The HQ has been defined so that if it is less than 1.0, there should be no significant risk or systemic toxicity. Ratios above 1.0 could represent a potential risk. When exposure involves more than one chemical, the sum of the individual hazard quotients for each chemical is used as a measure of the potential for harm. This sum is called the Hazard Index (HI).

$$HQ = CDI / RfDo \quad (2)$$

$$HI = \sum HQ \quad (3)$$

CDI is the Average daily Intake while the RfD is the Oral Reference dose. Oral reference dose of metals under investigation are Pb, Cu, Zn, Cr and Ni values were 0.004, 0.040, 0.300, and

mg/kg/day, respectively[15]. All calculations are done with the assumption that roasted goat meat will be washed before consumption but HI of roasted and washed was used to compare with that of control samples and roasted and unwashed.

2.8. Statistical analyses: Collected data obtained from various parameters of goat meat and hide samples were subjected to mean ± standard deviation (SD). Range of concentration of analyte in samples was also included.

III. RESULTS AND DISCUSSION

Table 1 shows that roasting goat meat with rubber tyres deposited high levels of Heavy Metal content onto (and into) the meat. Although washing the burnt goat meat after roasting considerably reduced this heavy metal deposition, it did not completely rid the goat meat of these deposits. Cobalt and Manganese were not detected for all twenty-eight test solutions. The table shows concentration levels of all four analyte metals that were detected. The observed trend shows a significant difference in the concentration levels of Lead (Pb), Zinc (Zn) and Copper (Cu) determined in Roasted unwashed samples relative to roasted and washed samples. Although, Iron content of goat meat depends on the type or specie of goat. It also depends on the part of the goat been analyzed. Snezana et al.,[16] found 7.25mg/kg Iron content in the kidney of Serbian white goat and 6.51mg/kg in the kidney of Balkan goat. The results for concentration levels of Iron (Fe) in all the samples indicate that the roasting process with rubber tyre as fuel source raises the iron content of goat meat above the recommended daily intake of 3.2mg[17] (Correa, 2011). RUW samples have iron content which exceeded the daily intake of 3.2mg while the RW samples had concentration values which were just within limits. The fact that Cobalt and Manganese were both not detected in all sample test solution may be an indication that none of these metals are used in the formulation of vehicular tyres and they do not occur naturally in goats. Methods of processing of animals like fermentation methods may likely not contain metals like Cadmium and Lead[18] (Akwete et al.,2013).

Concentrations of Pb found in all samples exceeded the Maximum Permissible Limits (MPLs) in meats. The USDA (2006)[19], reported the MPLs of Cu, Zn, and Pb in meat as 20mg/kg, 50mg/kg and 0.1mg/kg respectively. In this study, only the control samples had concentrations of Pb within the permissible limits. This makes the scalded method a better method for removal of hair from animal hides since it reduces the Pb content to a good extent than the roasting process. Also, for Zn and Cu, all samples are within the permissible limits irrespective of whether roasted unwashed or roasted washed although their concentration in samples reduced from RUW to CS samples indicating that the roasting process may have in a way increased their values in RUW sample. Consumption of high concentration of lead from food sources can lead to anemia especially in children since lead competes with iron for absorption in the body. Lead is a particularly pernicious metal to iron metabolism and it can also be taken up by iron absorption machinery (DTM1) and therefore blocks iron through competitive inhibition. Lead also interferes with a number of important iron-dependent metabolic steps[20] (Abbaspour et al; 2013)

Table 1: Mean and Range of metal concentrations (μg/g) in various samples of goat meat collected

RUW1	Mean ± SD	26.06 ± 1.23	2.53 ± 0.12	5.09 ± 0.45	46.175 ± 12.5
	Range	25.34 – 27.48	2.40 – 2.60	4.81 – 5.61	44.92 – 47.22
RUW2	Mean ± SD	22.54 ± 1.22	2.13 ± 0.11	4.47 ± 0.71	45.173 ± 2.19
	Range	21.14 – 22.26	1.93 – 2.19	3.97 – 5.274	44.96 – 45.39
RUW3	Mean ± SD	25.21 ± 2.12	2.38 ± 0.19	3.29 ± 0.29	49.03 ± 1.09
	Range	27.46 – 23.26	2.20 – 2.59	2.97 – 3.57	48.94 – 49.15
RW1	Mean ± SD	11.05 ± 1.20	1.04 ± 0.11	0.37 ± 0.01	26.59 ± 3.72
	Range	10.35 – 12.43	0.99 – 1.17	0.39 – 0.411	26.18 – 26.91
RW2	Mean ± SD	11.16 ± 1.23	0.99 ± 0.19	0.79 ± 0.08	27.27 ± 1.77
	Range	10.45 – 12.58	0.79 – 1.19	0.713 – 0.87	27.17 – 27.47
RW3	Mean ± SD	12.23 ± 2.04	1.16 ± 0.19	0.35 ± 0.01	12.81 ± 2.67
	Range	10.58 – 14.51	0.99 – 1.37	0.33 – 0.357	12.49 – 12.98
RW4	Mean ± SD	17.45 ± 1.05	1.65 ± 0.01	0.13 ± 0.1	24.748 ± 2.41

	Range	16.77 – 18.67	1.58 – 1.76	0.022 – 0.19	24.49 – 24.98
CS1	Mean ± SD	2.09 ± 0.009	0.197 ± 0.01	4 x 10^{-4} ± 0.1	12.44 ± 1.69
	Range	2.08 – 2.10	0.196 – 0.198	0.0004	12.28 – 12.614
CS2	Mean ± SD	2.08 ± 0.005	0.266 ± 0.12	2 X 10^{-3} ± 0.0002	12.74 ± 1.72
	Range	2.07 – 2.09	0.196 – 0.404	0.0 02	12.55 – 12.88

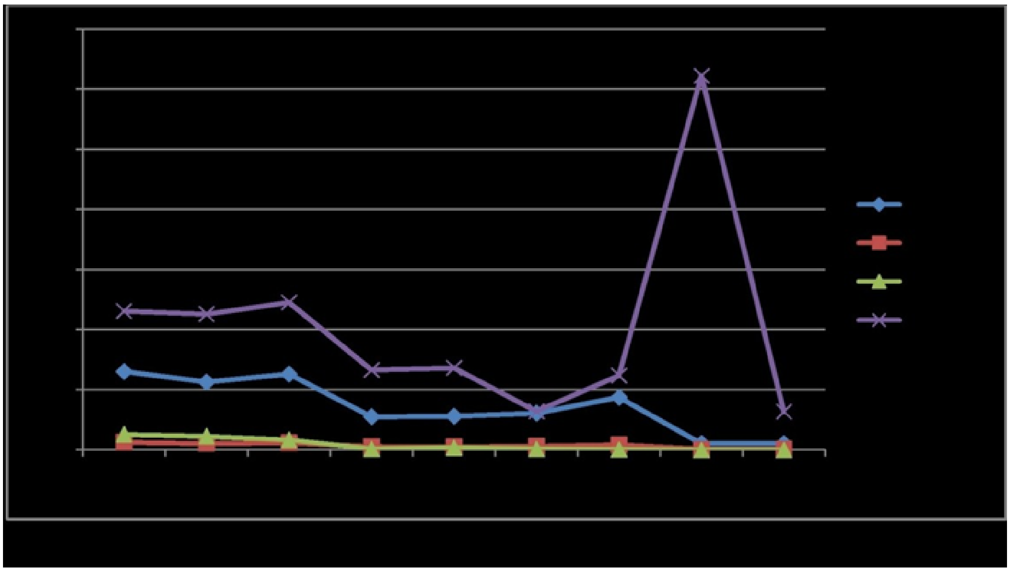

Figure 2: Mean concentration of heavy metals in goat meat and hide samples

Table 2 shows that levels of DEHP deposited on roasted goat meat reduced after washing but for lower Molecular weights Phthalates such as DiBP, their levels remain relatively constant even after washing the roasted goat meat. This trend is also observed for PAHs as reported in Table 3 below. The relatively constant levels of Fluorene and Phenanthrene suggests that lower molecular weight PAHs penetrate the pores of the goat hide and are not necessarily deposited just on the surface of the slaughtered goat meat. As a quality control measure, recovery studies of DEHP and Fluorene was carried out. Results gave a recovery of 86% for DEHP and 92% for Fluorene.

Table 2: Concentration levels of Four Phthalate Esters determined in various samples of goat meat

Sample ID	**DMP (µg/g)**	**DEP (µg/g)**	**DiBP (µg/g)**	**DEHP (µg/g)**
CS1	N.D	N.D	1.1521	2.7101
CS2	N.D	N.D	2.8346	–
RW1	N.D	N.D	2.7541	5.6999
RW2	N.D	N.D	5.3712	1.6701
RW3	N.D	4.5630	4.7703	6.5011
RW4	N.D	7.0746	2.8397	3.9249
RUW1	N.D	N.D	3.0414	92.4972
RUW2	N.D	N.D	4.3004	85.9806
RUW3	N.D	N.D	2.0199	138.9254

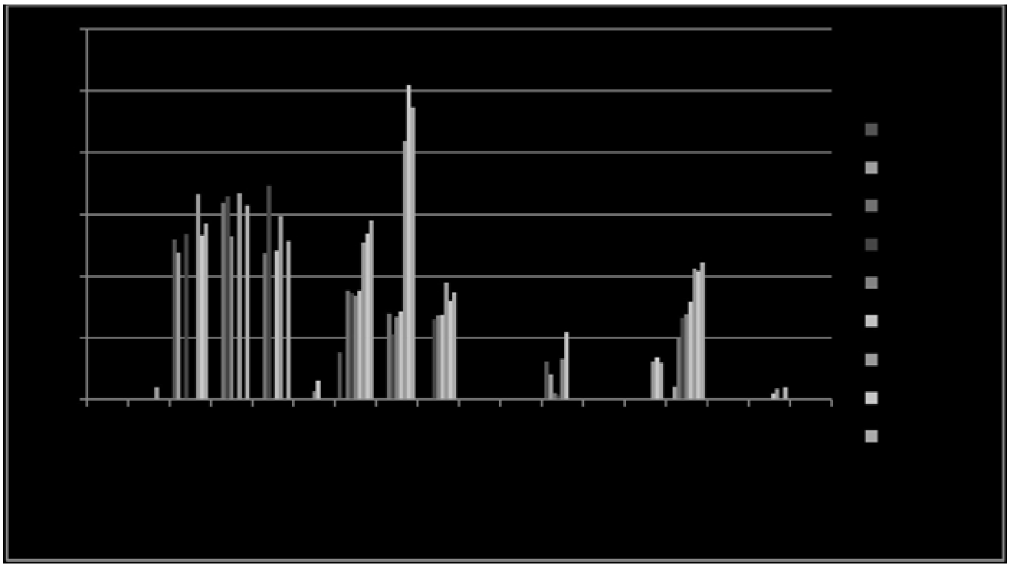

Figure 3: Concentration of phthalate esters in goat meat and hide samples

From Table 2, DEHP has its highest concentration of 138.9254**µg/g** in RUW3 with the lowest sample containing 1.6701**µg**/g in RW2**.** Roasted and washed samples have considerably the lowest concentration of DEHP with concentration of1.6701 **µg/g** while one of the control samples had a concentration of 2.7101 **µg/g**. This could be in the food or water given to the animal before slaughter. The food or water may have been in contact with food contact materials in which DEHP is commonly used as plasticizers. Also, DEHP is one of the compounds used for flooring materials and also a major plasticizer for medical products[21]since some of these animals may have been administered with drugs for one reason or the other, DEHP may have leached into the drug used from the medical product in the process of administration or storage. This may have been accumulated in the system. DiBP had concentrations ranging from 1.1521 **µg/g** to 5.3712 **µg/g** including control samples. Control samples which were not roasted with tyres may have contacted

DiBP from feeds and plasticizers which may have leached into water. DEP was detected in only two samples (RW3 and RW4) with concentration of 4.5630**µg/g** and 7.0746**µg/g** respectively. This obviously revealed sources of phthalates other than deposits of roasting with tyres after animal slaughter. Dimethyl Phthalate was not detected in all the samples. This may be because it was not the particular plasticizer used in food contact materials used for animal feeding.

Table 3 below shows PAH content of CS, RUW and RW samples, RW samples had lower concentrations of PAHs than the RUW. Pyrene had the highest concentration of 50.85**µg/g** in RUW2 while Benzo (b, k) fluoranthene had the lowest concentration of 0.751**µg/g** in SW2. PAHs like Naphthalene and Chrysene were not detected at all in all samples analyzed. Chrysene was not detected in all samples analyzed by Nnaji et al, 2017[22]. Control samples contained three PAHS each. Both control samples had Acenaphthene and Benzo(b,k)pyrene.Acenaphthene concentrations in both control samples were lower than those in roasted washed samples and roasted unwashed samples. This shows the effect of washing on the samples. Benzo (b, k) fluoranthene was not detected at all in the RUW samples, but was evidently found in all control samples and the RW samples. Samples may have contacted PAHs from other sources other than the goat meat samples. Benzo (a) pyrene which is the most carcinogenic PAH has MCLs set as 2**µg/kg** is present in all RUW samples with concentration values higher than the maximum contamination limits set by EU. The concentration obtained in RUW samples were higher than those obtained by the study carried out by Mottier et al., 2000[23] where mean value of 130µg/kg was obtained in barbequed cattle and goat. Average background values for Benzo (a) pyrene concentration ranged between 0.01-1.0µg/kg in uncooked meat sample.[24]

Table 3: Concentration Levels (µg/g) of PAHs determined in various goat meat samples

PAHs	CS1 µg/g	CS2 µg/g	RW1 µg/g	RW2 µg/g	RW3 µg/g	RW4 µg/g	RUW1 µg/g	RUW2 µg/g	RUW3 µg/g
Naphthalene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Acenaphthylene	N.D	N.D	N.D	N.D	N.D	N.D	1.97	N.D	N.D
Acenaphthene	25.88	23.77	N.D	26.72	N.D	N.D	33.19	26.5	28.43
Flourene	N.D	N.D	31.84	32.91	26.4	N.D	33.4	N.D	31.43
Phenanthrene	N.D	N.D	23.66	34.65	N.D	24.05	29.63	N.D	25.62
Anthracene	N.D	N.D	N.D	N.D	1.27	3.06	N.D	N.D	N.D
Flouranthene	7.56	N.D	17.59	17.16	16.75	17.63	25.36	26.8	28.91
Pyrene	N.D	N.D	13.89	10.52	13.33	14.21	41.78	50.85	47.27
Benzo(a) Anthracene	N.D	N.D	N.D	12.89	13.59	13.69	18.88	15.99	17.3
Chrysene	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Benzo(b,k) Flouranthene	6.11	4.01	1.06	0.75	6.54	10.86	N.D	N.D	N.D
Benzo(a)pyrene	N.D	N.D	N.D	N.D	N.D	N.D	6.12	6.79	5.92
Dibenz(a,h) Anthracene	N.D	2.07	9.99	13.19	13.83	15.81	21.2	20.74	22.19
Benzo(g,h,i) Perylene	N.D	N.D	N.D	N.D	N.D	0.94	1.74	N.D	1.93

Figure 4 below shows a line chart of Polycyclic aromatic hydrocarbons found in the goat meat and hide samples analyzed. The chart shows that pyrene has the highest concentration. Although pyrene is not as problematic as Benzo (a) pyrene but animal studies have shown that pyrene is toxic to kidneys and liver. Pyrene is a low molecular weight PAH (PAHs with two to four aromatic hydrocarbon rings) and they are more potent as co-carcinogens during promotional stage of cancer.[25] The human metabolite of pyrene which usually goes into the environment is 1-hydroxypyrene, it is usually found in the urine. It has also been found in the urine of outdoor workers exposed to air pollution. On getting into the environment, 1-hydroxypyrene may have adverse

effects on environmental organisms like algae and fish. 1-hydroxy pyrene has been a useful biomarker for assessing exposure to environmental polycyclic aromatic hydrocarbons.

[26] Van Rooji et al., (1994)[27] from their research found out that consumption of food products and active smoking accounted for 99% of total pyrene intake.

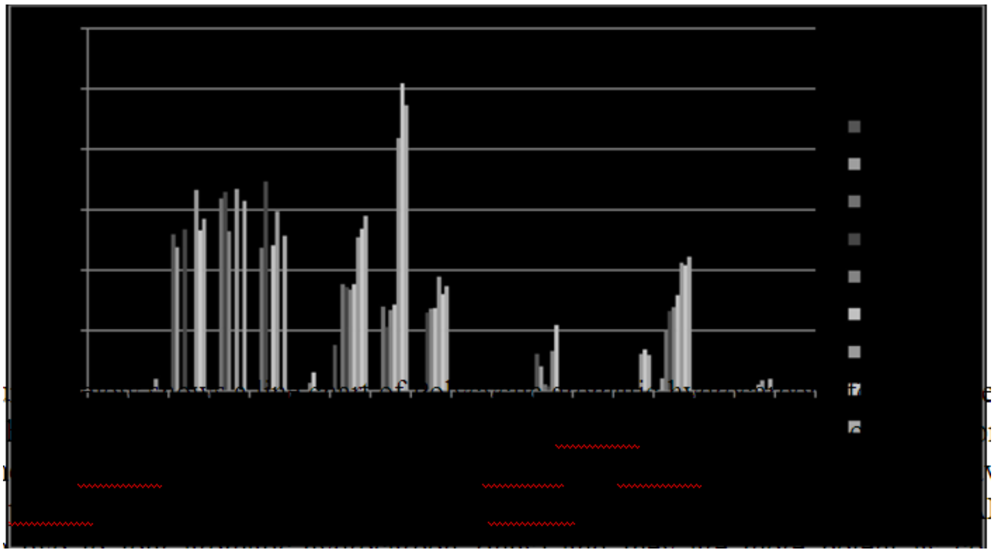

Figure 4: Mean concentrations of Poly aromatic Hydrocarbons in goat meat and hide samples

Benzo (a) pyrene which has been classified as Group 1 carcinogen was found in the range of 5.92- 6.79 µg/g in all Roasted and unwashed samples. This may have deleterious effects on consumers of such meat samples if not properly washed before consumption. This is because Benzo (a)pyrene is capable of causing mutagenicity and carcinogenicity28, DNA damage and oxidative stress 29, Impaired male fertility30 Respiratory diseases31, Cognitive dysfunction among children32 etc. All samples except CS1 contained Dibenz (a,h) anthracene while Anthracene is present in two of the samples only. Anthracene is usually used as diluents for wood preservatives33 and which may have been deposited as a result of burnt wood used in the roasting process. The presence of acenaphthene, phenanthrene, fluorine and fluoranthene may be as a result of them been used in the manufacture of agrochemicals, pesticides and pharmaceuticals33 (Abdel- Shafy and Monsour, 2015). Residues of these may be in food and drugs administered to goats and possibly may have accumulated in their body system. Since PAHs can get into the system either by inhalation, dermal contact, from soils or by ingestion, any of these sources may have been responsible for the contamination of goat meat and hide samples analyzed. Oko and Okoye (2017)34 determined PAHs in cow hides and found PAHs in all samples unroasted and roasted samples. Their study revealed that the mean concentration of phenanthrene was the highest and that of naphthalene the least with mean values of 0.6817±0.1429µg/kg and 0.0027±0.0005µg/kg respectively. The present study did not detect naphthalene and chrysene in all samples analyzed but had lower values of PAHs compared to that Oko and Okoye (2017). Ofomata et al., (2019)35 has analyzed goat skin for PAHs and found PAHs in all samples of goat skin both unsinged and singed with pyrene having the highest mean values both in singed and unsinged goat skin with mean concentrations of 35.01±13.36µg/kg and 123.77± 59µg/kg. Concentration of acenaphthene in all samples were the lowest with 0.40±0.00 µg/kg and 0.70 ±1.05µg/Kg for unsinged and singed samples respectively. Mean concentration values of pyrene found in this present study is lower than those values obtained by Oformata et al., (2019) although pyrene was not detected in our present study. Human Health Risk Assessment: Human health risk associated with the consumption of goat meat roasted with rubber Tyre was assessed by calculating the Health Quotient (HQ). According to the US EPA IRIS 2006 report15, the value of HQ depends upon the average daily intake of the contaminant through ingestion and the oral reference dose (Rfd)

Table 4: Calculated Hazard Quotients for phthalate esters contained in goat meat samples.

PHTHALAT EESTER	Structural Formula	CAS Number	Oral Ref. Dose (mg/kg/Day)	Calculated Hazard Quotient
Dimethyl Phthalate	C10H10O4	131–11–3	N.A	cc
Diethyl Phthalate	C12H14O4	84–66–2	0.8	0.0036
Di-isobutyl Phthalate	C16H22O4	84-74-2	0.1	0.0197
Diethylhexyl Phthalate	C24H38O4	117–81–7	0.02	0.1112

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Results obtained substantiate the claim that rubber tyre roasting of goat meat in the abattoir, deposits compounds that are detrimental to humans. Levels of Benzo[a]pyrene found in RUW samples were much higher than 0.0012µg/g obtained by Nnaji et al (2017)[22] in smoked meat and hides. Market ready RW samples however, showed no traces of Benzo[a]pyrene thereby satisfying EU[36] limit of 0.002µg/g for Benzo[a]pyrene. The European Commission Regulation (EU) of 12 December 2014 amending regulation (EC) No1881/2006 as regards maximum levels of Polycyclic aromatic hydrocarbons (PAHs) in traditionally smoked meat and meat products and traditionally smoked fish and fishery products gave limits of 5.0 µg/kg for benzo(a)pyrene and 30.0 µg/kg for the sum of benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene. Results obtained from this study shows that limits set by the EU has not been exceeded both for RUW and RW samples although Chrysene was not detected in all samples analyzed and benzo(b)fluoranthene was not determined. Values obtained for most of the PAHs determined follow the trend observed by Aya and Nwite [37](2016).

This suggests that washing the burnt carcass considerably removes deposits. Mean copper (Cu) concentrations reported in Ekenma et al., (2015)[38] of 6.08µg/g were three times higher than levels found in this study. Levels of Lead (Pb) found in our samples exceeds the EC permissible limit of 0.01µg/Kg. Although there was a marked decrease in Lead concentration after washing, concentrations obtained from SW samples were still above the permissible limit. Compounds like Polycyclic Aromatic Hydrocarbons, Phthalates and Heavy Metals are deposited in quantities that pose a severe health risk to consumers of this kind of meat. Associated health concerns may arise in the long-term (Chronic effects) and these compounds are known to be characteristically bio- accumulative. There could be also a risk of transfer from mother to child via breast-feeding and even mother to unborn child via the placenta.

IV. CONCLUSION AND RECOMMENDATION

This research has revealed that heavy metals, phthalate esters and polycyclic aromatic hydrocarbons can be deposited onto and into goat meat roasted as one of the processes for preparing goat meat for human consumption thereby raising health concerns. Since the health risk assessment in this study has shown that a lot of risk is associated with consuming goat meat roasted with tyres especially when unwashed, it is therefore advisable to ensure that human health is been preserved from the carcinogenic and mutagenic effects of chemicals inherent in roasted goat meat sold to the general public. the primary process for preparation of any slaughtered livestock that is to be consumed by humans.

Regulations to ban the use of expired tyres for roasting animals meant for human consumption should be put in place with a monitoring team attached so that there will be proper compliance.

In addition to health concerns, the use of expired rubber tyres for goat meat roasting also poses a serious environmental threat. Some of these compounds deposited onto the slaughtered goat meat are also released into the atmosphere and water bodies, eventually becoming pollutants that are more difficult to track or control. Furthermore, we cannot overlook the economic impact, as a consequence of the consumption of goat meat onto which these compounds have been deposited; health effects would translate into a reduced lifespan thereby reducing the number of healthy workforce available for effective and proper functioning of the economy. For food security, to protect our health, the environment and in line with the sustainable development goals of the United Nations, an outright ban on the use of rubber tyres as fuel for goat or general livestock roasting should be imposed. A take back programme may be initiated for expired tyres for easy collection and handling. There should also be a shift to cleaner sources of fuel for roasting processes in slaughter houses and abattoirs but more importantly, the use of hot water scalding should be made the regulations. Awareness should be created among local butchers and the entire populace on the dangers and health risks associated with consumption of roasted goat meat. Also, laboratories should be situated in abattoirs with test kits for prompt assessment of the presence of harmful chemicals in roasted meat before been dispatched to markets for sale to consumers. All these steps would reduce to the barest minimum, levels of pollutants deposited onto the prepared goat meat which may in turn end up in the environment when eventually consumed by man.

Disclosure statement
The authors declare that there are no conflicts of interest.

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