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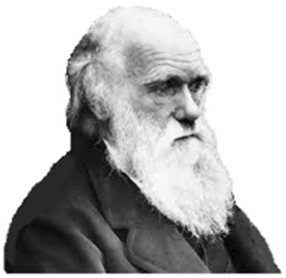

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Polycyclic Aromatic Hydrocarbon Accumulation in Meats Singed with Kerosene and Waste Tyres: A Case for Public Health Concern in Nigeria

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ABSTRACT

Singeing is a common post slaughtering process of livestock and this has been associated with the introduction of high level of Polycyclic Aromatic Hydrocarbon (PAH) in the meats. There is dearth of information on alternative singeing technology for safe meat. Therefore, this study is aimed at proffering an alternative method for singeing livestock carcass as a post-slaughtering process to reduce accumulation of PAH in meat. An experimental study, involving the use of a singeing device (singeing torch) sourced locally was conducted. Singeing was carried out on a sacrificed goat using conventional methods and the Singeing Torch (ST). Five grams of meat samples singed with kerosene, tyres and the ST were collected from two abattoirs and observed for physical qualities. The physicochemical properties such as pH and PAH were determined using standard procedures. Results were compared with International Agency for Research in Cancer guidelines. Data were analyzed using descriptive statistics and ANOVA at 5% level of significance. Bright appearances with red coloration for ST singed meat while black patches and dull appearances were observed on meat singed with kerosene and tyres respectively. ST singed meat showed a better olfactory quality, a more neutral PH value and PAH of 7.3 and 3.30 (n/ng), while kerosene and tyre singed meat showed 6.8 pH value, 4.20 (n/ng) and 6.61 (n/ng) respectively with mean of 0.194±0.56, 0.248±0.94 and 0.389±1.21 respectively. The principal PAH compounds in ST meat identified were 1-Methylnaphthalene, 2-Methylnaphthalene, Acenaphthene, Pyrene and Benz(a)anthracene. This study indicates that meat singed with ST had lower PAH contents and better physical quality. The use of device and method that generates no chemical contaminants such as the ST should be encouraged for the singeing process of livestock carcasses as a strategy for the control of chemical contaminants of meat.

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***Keywords*:** Singeing torch, Meat, Waste Tyres, Kerosene, Poly Aromatic Hydrocarbon (PAH)

1. INTRODUCTION

Meat is a whole part of any buffalo, camel, cattle, deer, goat, hare, pig, poultry, rabbit or sheep, slaughtered other than in a wide state, but does not include eggs, or fetuses (Peter, 2007). It also includes offal (i.e. meat other than meat flesh, including brain, heart, kidney, liver, pancreas, spleen, thymus, tongues and tripe), excluding bone marrow and are valuable sources of vitamins A, B1 and nicotinic acid (Cross and Overby, 1988). Meat is animal flesh that is eaten as food and is an indispensable source of some major nutrients; though meat is a very good source of essential amino acids, vitamins, minerals and essential fatty acids, it is not relied on for vitamins and essential fatty acids in a well-balanced diet (Lawrie, 1991). Cattles are transported to the abattoirs where slaughtering and post-slaughter procedures like-skinning, scalding, dehairing, singeing, polishing etc. are carried out. Methods such as singeing off the hairs of the animals with flame fuelled by various substances such as wood mixed with spent engine oil, plastics mixed with refuse or tyres (Nkansah and Ansah, 2014) have been some of the ways by which slaughtered animals are being processed. However, the relative scarcity of firewood in recent times has resulted in local butchers using scrap tyres (Obiri-Danso *et al.*, 2008), which is one of the major public health concerns especially in developing countries where this is carried out.

Operators of Akinyele and Bodija abattoirs in Oyo State, Nigeria, where this study was carried out confirmed this past reports, as tyres and kerosene were used as fuel for the singeing process and have been seen to have grievous effects of contamination such as with heavy metals. These heavy metals are of public health concern because of their toxicity, bioaccumulation and bio magnifications in the food chain (Nkansah and Ansah, 2014). These pollutants often have direct physiological toxic effects because they are stored or incorporated in tissues which might leave residues that are not metabolisable. The burning of tyres releases environmental pollutants which contain hazardous substances such as styrene and 1,3-butadienes (Holder *et al.*, 1991).

Tyres also contain several metals such as lead, mercury, cadmium, chromium, zinc, and arsenic which could contaminate hides when used as source of fuel (Okiei *et al.*, (2009) and Ekenma *et al.*, (2015)). Anf H. Ziadat and Emad Sood (2014) reported that Environmental Protection Agency (EPA) does not consider scrap tyres to be hazardous, but the burning of the scrap tyres is documented to be hazardous due to the array of carcinogenic, teratogenic, and mutagenic chemical compounds emitting from the process.

According to Obiri-Danso *et al.* (2008), singeing is largely favored in many respects in African countries, as it offers the carcass hide for consumption and a delicacy which is highly acceptable by the local populace, but the processing methods have to be evaluated to prevent consumption of meat causing more harm than good, as meat is a wide source of animal protein (high biological value protein) consumed by majority except acclaimed Vegetarians. There is therefore, the need for responsive action towards this public health concern because of the health implications of singeing meats using materials that could contaminate it and also owing to the fact that safe or liquefied petroleum gas for singeing has not being properly understood by the butchers.

In addition, the standards and regulations for carcass processing abattoir operations in developing countries and specifically in Nigeria are often not adhered to, as most butchers are only concerned about the low costs of these post slaughter processes, since it is an energy-consuming process. They are not concerned about the toxicological impact and health of the consumers.

Literature revealed that the materials often used for singeing slaughter animals include: scrap tyres, wood mixed with spent engine oil, plastic mixed with refuse, plastic wastes which are individually toxic and have public health and environmental implications. Many researchers have ascertained the toxicological effects of these sources of fuel for singeing meat. However, they have not readily come up with affordable and accessible interventions for the butchers to carry out this post slaughter process in order to save cost of meat production and also sustain public health to a large extent.

Most work carried out by researchers in this field failed to conduct analysis for the PAH content and other contaminants such as Volatile Organic Compounds- dioxins and furans in meat and in the exposed butchering environment. This is mainly due to the use of inappropriate singeing methods and concern for analysis of heavy metals in the singed meat only.

To address this important public health problem in developing countries and specifically in Nigeria, a study of this nature involving the use of propane-powered singeing torch that is adjudged to be affordable and readily accessible for domestic and abattoir uses, aim at assessing the physicochemical qualities of meat, including poly aromatic hydrocarbon content will be useful and timely. The findings would be useful in proffering solution to the common use of tyres, kerosene and related materials for singeing carcass and also for policy formulation.

2. MATERIALS AND METHODS

2. 1. Study Location

The study was conducted in Akinyele and Bodija abattoirs in Ibadan, while the laboratory analysis was done at Geo-environmental Research Centre (GRC) laboratory; Basel Convention Coordinating Center, Ibadan, Nigeria.

2. 2. Study Design

The study was exploratory in design with field experiment and laboratory component. The study involved the use of new singeing torch, followed by a pilot testing of the device at animal slaughter and meat dressing unit of 2 major abattoirs in Ibadan metropolis.

2. 3. Singeing materials and the device used for the study

The singeing materials used for this study include kerosene and waste tyres for the convectional singeing method, while a singeing device (singeing torch) was acquired for the purpose of achieving safe singeing process. The equipment works on air movement and powered by liquefied petroleum gas – propane, under high velocity and pressure to burn at the wide tip of the gas blower.

The choice of gas propane instead of butane was due to the fact that it has a lower boiling point and can convert easily from a liquid to gas even in very cold conditions, down to -45 °C; when stored as a liquid in a tank. It also exerts a greater pressure than butane even at the same temperature, hence making it most suitable for exterior storage, usage and it can be stored for

a longer time. The singeing torch has features that fit into various weather conditions and meat singeing process as an outdoor activity.

It has automatic ignition which enables flame exhaustion from the vent through a narrow opening that brings out the oxygen-rich flames under high velocity and pressure.

2. 4. Poly aromatic hydrocarbon analysis

The 17 principal compounds of PAH was assessed for each of the singed meat samples; singed with tyres, kerosene and singeing torch, using gas chromatography with mass spectrophotometry(GC-MS).

2. 5. Assessment of physical qualities in meat samples

The qualities of the meat were assessed using visual observations and special apparatus

2. 5. 1.Water activity:

It was measured using water activity meter and also the shelf life of each meat sample singed with tyre, kerosene and singeing torch were assessed by storing pieces of these meats for duration of one week to ascertain which singeing method enabled the highest shelf life

2. 5. 2. Water holding capacity:

This was assessed using filter-paper press technique for which meat samples were placed on humid filter papers which were placed between plexi glass plates (hard surfaces) and subjected to specified pressure. Ratio of meat area to expressed juice area determines water holding capacity; if ratio of expressed juice area to meat area is high it is indicative of low water holding capacity. The result also accounts for muscle firmness and wetness, drip loss.

2. 5. 3. Meat Texture:

The meat samples were assessed by touch and its mechanical rigidity when subjected to cutting using cutting device analysis which is similar to Warner-Bratzler's test for measuring meat texture. Meat with high water holding capacity have tough texture, also presence of fat marbling gives soft texture.

2. 5. 4. Muscle Firmness or Wetness:

This can either be Soft and Exudative (SE), Firm and Normal (FN) or Firm and Dry (FD). This can be accounted for by the results for meat texture and water holding capacity.

2. 5. 5. Soft and exudative:

The meat has no shape and the moisture drips from meat (pale colored-pale soft exudative meat), gives drier texture when cooked.

2. 5. 6. pH

This was measured electrochemically using solid state (IS-FET) electrodes.

3. RESULTS

3. 1. Physical qualities of the singed meat

The physical quality of the kerosene-singed meat, tyre-singed meat and torch-singed meat are as shown in Table 1. The indicators include: water holding capacity, texture, appearance, muscle firmness and wetness, pH, colour, mechanical rigidity etc.

Table 1. Comparison of physical qualities of meat samples between the conventional singeing methods and the use of Singeing Torch

S/N	Physical qualities	Kerosene-singed meat	Tyre-singed meat	Torch-singed meat
1	Water holding capacity	Low water holding capacity (ratio of expressed juice area to meat area is high in using filter-press method)	High water holding capacity (ratio of expressed juice area to meat area is low in using filter-press method)	Low water holding capacity (ratio of expressed juice area to meat area is high in using filter-press method)
2	Meat texture	Soft but highly elastic	Soft but highly elastic	Normal texture
3	Appearance	Black patches on meat	Dull colour	Brighter and more appealing skin color
4	Muscle firmness and wetness	Firm and normal (non exudative)	Firm and normal (non exudative)	Firm and normal (red, firm and non exudative)
5	Colour	Unstable pink signifying the presence of Nitric oxide	Unstable pink signifying the presence of Nitric oxide	Red signifying presence of Oxygen (Oxymyoglobin)
6	Odour/flavor	Normal meat odour	Normal meat odour	More aroma/flavor
7	Mechanical rigidity	Tougher in cutting	Tougher in cutting	Easier to cut
8	pH	6.8	6.8	7.3
9	Water activity (Shelf life)	0.98	0.98	0.98

3. 2. Polyaromatic Hydrocarbon (PAH) content of the singed meat

The polyaromatic hydrocarbon contents of the singed meat are as shown in Table 2. These include: 1-Methylnaphthalene, 2-Methylnaphthalene, Acenaphthene, Phenanthrene, Pyrene, Benz(a)anthracene, Indeno(1,2,3-cd)pyrene etc.

Table 2. Comparison of polyaromatic hydrocarbon content in meat samples singed with the conventional singeing methods.

S/N	PAH (ng/g)	Kerosene-singed meat	Tyre-singed meat	Meat sample singed with Torch
1	1-Methylnaphthalene	0.14	0.14	1.14
2	2-Methylnaphthalene	3.88	5.05	2.10
3	Acenaphthylene	ND	0.72	ND
4	Acenaphthene	0.02	0.02	0.02
5	Fluorene	ND	0.01	ND
6	Phenanthrene	0.01	0.09	ND
7	Anthracene	0.01	0.06	ND
8	Fluoranthene	ND	ND	ND
9	Pyrene	ND	ND	0.01
10	Benz(a)anthracene	0.15	0.05	0.04
11	Chrysene	ND	ND	ND
12	Benzo(b)fluoranthene	ND	0.36	ND
13	Benzo(a)pyrene	ND	0.02	ND
14	Benzo(k)fluoranthene	ND	0.03	ND
15	Indeno(1,2,3-cd)pyrene	ND	ND	ND
16	Dibenz(a,h)anthracene	ND	0.06	ND
17	Benzo(g,h,i)perylene	ND	ND	ND

ND: Not detected

Table 3. Association between the meat singeing methods using ANOVA.

Poly aromatic hydrocarbon								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Kerosene	17	.2476	.93723	.22731	-.2342	.7295	.00	3.88
Tyre	17	.3888	1.21500	.29468	-.2359	1.0135	.00	5.05

Singed Torch	17	.1947	.56276	.13649	-.0946	.4841	.00	2.10
Total	51	.2771	.92826	.12998	.0160	.5381	.00	5.05

Poly aromatic hydrocarbon					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.342	2	.171	.192	.826
Within Groups	42.741	48	.890		
Total	43.084	50			

The results using ANOVA showed that tyre-singed meat had the highest mean PAH of 0.3888, followed by that of kerosene- singed meat 0.2476, with the least being that of singeing torch 0.1947; of which the p value of 0.826 as shown in Table 3 was obtained which is greater than 0.05 showing that the results can be attributed to chance. The detail comparison of the meat processing method showing the statistical significance is as given in Table 4.

Table 4. Multiple Comparisons (Post- hoc test).

(I) Meat Processing Method	(J) Meat Processing Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Kerosene	Tyre	-.14118	.32366	.901	-.9240	.6416
	Singed	.05294	.32366	.985	-.7298	.8357
Tyre	Kerosene	.14118	.32366	.901	-.6416	.9240
	Singed	.19412	.32366	.821	-.5887	.9769
Singed	Kerosene	-.05294	.32366	.985	-.8357	.7298
	Tyre	-.19412	.32366	.821	-.9769	.5887

The results of the analysis in Table 2 showed that PAH is higher in meats singed with tyres compared to those singed with kerosene and singeing torch; with singeing torch having the lowest amount of PAH, this is explainable as PAH accumulation is acquainted to soot formation and the use of the torch on the meat sample did not lead to the release of soot, hence it is a healthier option for improved public health practice.

Seventeen principal PAH compounds were tested and assessing the compounds individually showed that 2-Methylnaphthalene had the highest amount for the meat samples using the three methods of singeing compared. It can be seen that 12 of the principal PAH compounds were not detected in the meat sample singed using the singeing torch. This shows that tyre which is majorly used by the butchers to singe the meat is of great public health concern. The physical qualities of meat samples using conventional singeing methods and the Singeing Torch are shown in Table 1.

4. DISCUSSION

Singeing is a highly energy-consuming process, hence the need for a cost-effective mechanism to carry out the process and singeing-torch affords this as it uses liquefied gas (propane), which is affordable, efficient since it produces more flames, less heat, no soot accumulation on the meat or nearby surroundings and easily accessible. The scrap tyres often used, selectively burns fur so does not crack the hides; these greatly adhere to the qualities the butchers noted in tyres that leads to its massive use in the process as seen in Amfo Otu *et al*. (2014) and Adam *et al.* (2013) reports. These reports revealed that the local butchers prefer scrap tyres to other means of singeing as it is cheaper and more efficient. It also produces more flames with less heat and selectively burns the fur without cracking the hides. The observed singeing torch efficiency contradicts Amfo Otu *et al.,* (2014) findings, which states that the butchers could not use liquefied petroleum gas facilities because they were not available and also the high cost when compared with the conventional methods they use.

According to Aremo *et al.* (2018), singeing duration of tyre singed carcass was highest after that of wood singed carcass, hence the reason for its consistent use when compared with the other methods such as kerosene, plastics, spent engine oils etc. Interestingly, singeing torch readily contradicts this report as it is faster because it works with the technique of high velocity and pressure using forced oxygen-rich air that enables increased flame at greater speed, showing its ability to be highly combustible and fast.

This study has shown that tyre-singed meat has the highest PAH contents followed by Kerosene-singed meat and singeing torch-singed meat the least PAH contents. This is consistent with findings from Emmanuel *et al.,* (2020). The researcher report revealed that the use of scrap tyres for singeing meat also pose a serious public health risk to people working in and living around those slaughter places as the open burning of the carcass releases volatile organic compound and PAH into the environment. Okiei *et al.,* (2009) and Ekenma *et al.,* (2015) also reported that hides singed with firewood and spent engine oil may contain certain compounds like poly aromatic hydrocarbons, dioxins, furans, benzene and lead. Mokrzyeki *et al.* (2003) in their study, revealed clearly that tyre wear debris contains heavy metals such as Mn, Fe, Co, Ni, Cu, Cd, Pb and other toxic substances which include PAH and VOCs; hence showing that the type of hazardous substances deposited on the meat depends on the substance used as fuel for meat processing.

This is also supported by Nnaji *et al.,* (2017) and Odoh *et al.,* (2017) who also agreed on the effects of processing on the contamination of food, as well as mode of storage and distribution. The reason for accumulation of PAH especially in meats singed with scrap tyres was illustrated by Hamparsun and Hilal (2010) that it is simply due to high temperature, oxidation, and incomplete combustion of organic compounds contained in the tyre

The use of singeing torch is a major approach geared towards improved public health status as it was produced primarily to ensure meat singeing without the accumulation of PAH so that consumers will not be expose to it. However, the little amount of PAH recorded in the meat singed by the singeing torch will definitely be due to the probable reasons also given by Moret *et al.* (1997). He stated that PAH formation occurs on or near the surface of meats and food cooked without being exposed to smoke does not show significant levels of PAH. Sikorski (2005) stated that lowering the temperature of smoke formation to 300-400 °C combined with the use of filters, reduces the PAH content by about 90%. The application process of the singeing torch does not lead to the release of smoke or soot as was clearly evident in the singeing process. The PAH present in the Torch singed meat was not statistically significant. Also, benzo(a)pyrene which is a surrogate marker for PAH compounds (Talaska *et al.* (1996) and Hussain *et al.* (2018) was not detected in the meat singed with the singeing torch and this in line with the findings of Talaska *et al.* (1996), which stated that liquid smoke allows for greater control of the level of toxic compounds. Yabiku *et al.* (1993) explained that the level of benzo(a)pyrene in liquid smoke flavour samples can vary substantially from not detected to 336.6 υg/kg.

Physical qualities greatly affect consumers' acceptability of meats. Omojola *et al. (*2006) study, showed how singeing can influence different physical qualities of meat. The study also revealed increase in flavor of singed meats when compared with their unsinged counterparts as noted in other previous studies. This was also evident in our study as the torch singed meat had a very strong flavor which is supported by Okiei *et al.*, (2009) and Ekenma *et al.,* (2015) reports that liquid smoke gives a more uniform flavor which is easier to reproduce, with normal meat flavor observed in the conventional singed meat. The study also found out that singeing reduces tenderness of meat when compared with scalding or skinning leading to lower moisture and lower water holding capacity. The presence of low water holding capacity was observed in the kerosene singed meat and the singeing torch meat only but all the meat samples were firm, normal and non-exudative (Omojola *et al.*, 2006).

The firm and non-exudative qualities of the meat samples supported Honikel *et al.*, (1986) and Offer *et al.* (1989) findings, as these suggested an increase in drip loss which is usually high in singed meats and it is the intracellular water which is lost from the muscle fibre post mortem driven by a pH and calcium induced shrinkage of myofibrils during rigor development, hence also accounts for muscle firmness. Singeing also increases the pH of meats compared to the other post-slaughtering processes. This is so because the meat samples had high pH values; which was also due to refrigeration done before the pH analysis was carried out as lower temperature is directly proportional to higher pH value.

5. CONCLUSION

This study confirms that meat singeing with singeing torch using propane gas had a normal, firm, improved meat quality and reduced PAH or VOCs compared with kerosene and tyres singeing meat. It also confirms that the tyres, kerosene, oil or plastics employed by the butchers to carry out this post-slaughter process lead to excessive chemical contamination of meat with carcinogens like poly aromatic hydrocarbon,

There is need for total ban of the use of kerosene, tyres and any other material (firewood, plastics, spent engine oil) that poses a great risk to public health. There is also the need for

consistent inspections of the abattoirs; sensitization of the butchers on how the health impacts of these singeing materials grievously outweighs the affordability and availability of these materials. The use of singeing torch should be encouraged, so as to reduce the carcinogens contaminated meats for improved public health status.

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