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**NUTRITIONAL VARIABILITY, EFFECTS AND SAFETY OF SMOKED MEAT IN DEVELOPING COUNTRIES**

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**ABSTRACT**

Smoked meat makes a valuable contribution to the diet in developing countries, because of its nutritional importance, as a source of protein, B-vitamin, iron, zinc and vitamin A and increased shelf-life of meat. Smoking of meat is not an absolute preserving method, the quality of raw material, the concentration of salt, heat through the smoking process, hygienic circumstances and heat of storage have important effects in reducing or increasing the risk of deterioration, as well as making the meat unsafe. The types of meat smoking includes, cold smoking, warm smoking, hot smoking, liquid smoke and smoke roasting. Nutritional variability in terms of percentage protein from different developing countries varies based on techniques of preparation and the extent of smoking involved. The effects of smoked meat processing includes the accumulation of potentially carcinogenic compounds such as phenanthrene, 2-methylnaphthalene, phenol, aldehydes, indene and naphthalene in smoked meat and certain microorganisms such as *Salmonella* species, *Pseudomonas* species, *Staphylococcus* species, *Bacillus* species and *Proteus* species, *Streptococcus* species and *Escherichia coli*. Thus, the presence of these contaminants in smoked meat calls for enhanced safety and standardization measures to mitigate these hazards. These measures include the use of clean utensils, safe drinking water for meat processing and adherence to the Hazard Analysis and Critical Control Point system. In addition, the quality of marketing conditions should be studied by producers for better understanding of changes in microbiological quality of the smoked meat during shelf-life.

**Keywords:** Smoked meat, Nutritional variability, Hazard Analysis and Critical Control Point, phenanthrene, 2-methylnaphthalene, phenol, aldehydes, indene and naphthalene.



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### INTRODUCTION

Meat smoking is the process of using hardwood or wood pellets upon incineration to generate smoke as a means of meat preparation. This action adds specific taste to the meat as well as increasing the shelf life of the meat. Smoked meat makes a valuable contribution to the diet in developing countries because of its nutritional importance, as a source of protein, fat, B-vitamin, Iron, Zinc, Vitamin A and amino acid needed to build, maintain and repair body tissues (Dashu *et al.*, 2017). Meat deterioration begins after the animal has been slaughtered due to chemical changes, enzymatic action and the action or presence of micro-organisms (bacteria, yeast and mold) which may result in oxidative rancidity, discoloration, moldiness, off flavor, sliminess. The major source of these deteriorative changes is the micro-organism and these renders the meat unacceptable and unfit for human consumptions (Forrest *et al.*, 2001).

The overall contamination of smoked meat with pathogens depends not only on the prevalence and numbers of the pathogens on the hair, skin, and in the intestinal tract of the animal, but is also on the degree of cross-contamination occurring during the slaughter and smoking process.

Notwithstanding the major role smoked meat plays in our meals, it can also serve as a rich medium of growth for harmful microorganisms. Meat is originally sterile and is contaminated after slaughtering with different psychrotroph, psychrophil and mesophil microbes from the environment (Corry, 2007). Psychrotrophic microorganisms grow at temperatures 0-20 °C, mesotrophic microorganisms 20-40 °C and thermotrophic microorganisms 40-65 °C; this means that the potential health hazards in meats are often from mesotrophic microorganisms since most of pathogenic microorganisms grow best at this range of temperature which coincides with human body temperature (37 °C) (Satish, 2004 and Jay, 2005).



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On the surface of chilled, aerobically stored meat, *Pseudomonas* species plays an important role and becomes dominant during storage (Greaser, 2001). Their metabolic activity (especially proteolysis and lipolysis) contribute to the spoilage as well as off-odour and slime formation (Greaser, 2001). The sources of these pathogenic microorganisms may be the animals themselves or the surroundings where the animals are kept or the way they are processed after slaughtering (Adeyemo, 2002). Smoked meat that is infected with microorganisms is normally poor in quality (Mukhopadhyay, 2009). The consumer needs to be provided with safe and wholesome smoked meat, which will not cause any health problem. This can be achieved by practicing better farm animal management, good personal hygiene and providing adequate knowledge on food safety to all the smoked meat handlers in the production chain (Haileselassie *et al.*, 2013 and Sofos, 2014). The effects of microbial contaminants on smoked meat include meat spoilage, food poisoning and condemnation of carcasses, which could result in reduction of income to farmers as well as smoked meat sellers. The consumers and meat handlers may acquire infectious diseases such as anthrax, *brucellosis*, *clostridiosis*, *erysipelas*, glanders, *leptospirosis*, *listeriosis* Q-fever, *salmonellosis*, *Staphylococcus* food poisoning, *streptococcosis*, tetanus, *tuberculosis* and *yersiniosis* due to poor handling of slaughtered animal and smoked meat (Adeyemo, 2002; Pal, 2007; Pal *et al.*, 2013).

Smoking of meat is not an absolute preserving method because of the following factors: quality of raw material, concentration of salt, water activity of the meat, heat through the smoking process, quantity of smoke, packaging, hygienic circumstances and heat of storage. These factors have important effects in reducing or increasing the risk of deterioration as well as causing harm to susceptible individuals when deteriorated meat is consumed (Ahmed *et al.*, 2011).



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### **HISTORY OF SOMKED MEAT**

Smoking as a way of preserving and flavoring meat has been in existence for thousands of years (Mintz, 1996; Azizieh, 2002). It is believed that smoked meat can be traced back to the primitive cavemen (Azizieh, 2002). As simple dwellings (caves) lacked chimneys, these structures would probably have become very smoky. Early humans would hang meat up to dry and out of the way of pests, thus accidentally becoming aware that meat that was stored in smoky areas acquired a different flavor, and was better preserved than meat that was simply dried out. This process was later combined with pre-curing the meat in salt or salty brine, resulting in a remarkably effective preservation process that was adapted and developed by numerous cultures around the world (Durham, 2001). The main goal of smoking was to preserve the meat so it would last longer without spoilage. Large quantities of salt were used in the curing process and smoking times were quite long, sometimes involving days of exposure (Azizieh, 2002).

In 1939 a device called the Torry Kiln was invented at the Torry Research Station in Scotland. The kiln was used for uniform mass-smoking and is considered the prototype for all modern large-scale commercial devices for smoking of meat. Although refinements in technique and advancements in technology have made smoking much easier, the basic steps involved remain essentially the same (Azizieh, 2002).



### **Characteristics of Smoked Meat**

- (i) Drying effect
- (ii) Desirable organoleptic properties
- (iii) Colour enhancement of cured meat
- (iv) Imparting antioxidants to the meat fat
- (v) Impregnating the outside portion of the meat with constituents of smoke that serve as antiseptics and germicides
- (vi) An adjuvant action of constituents of the smoke and heat if the process is carried out at a temperature above 49 °C
- (vii) Diminution of nitrite content, probably as a result of an aliphatic diazo reaction of protein which occurs at higher temperature
- (viii) Imparting of a desirable finish or gloss on both the skin and flesh of meat through the agency of aldehyde and phenol condensed resins from the smoke ( Ahmad *et al.*, 2005).

### **Types of Meat Smoking**

- (i) Cold smoking
- (ii) Warm smoking
- (iii) Hot smoking
- (iv) Liquid smoke
- (v) Smoke roasting

### **Cold Smoking**

Cold smoking differs from hot smoking in that the meat remains raw, rather than cooked throughout the smoking process (Casais, 2011). Smokehouse temperatures for cold smoking are typically between 20 to 30 °C (68 to 86 °F). (Myhrvold *et al.*, 2011). In this temperature range, the meat takes up a smokey flavor, but remains relatively moist. Cold smoking does not cook the meat, and as such, the meat should be fully cured before cold



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smoking (Myhrvold *et al.*, 2011). Meat is often hung in a dry environment first to develop a pellicle; it can then be cold smoked for several days to ensure it absorbs the smokey flavor. Cold smoking meat should not be attempted at home, according to the US National Center for Home Food Preservation: "Most food scientists cannot recommend cold-smoking methods because of the inherent risks of food poisoning (Khambadkone *et al.*, 2020). Cold smoking meat should only be attempted by personnel certified in Hazard Analysis and Critical Control Points (HACCP) to ensure that it is safely prepared (Livingston, 2010).

### **Warm Smoking**

Warm smoking exposes meat to temperatures of 25–40 °C (77–104 °F) (Fellows, 2009). It is used for meat and sausages. The food absorbs the smoke that is created from smoldering wood and becomes seasoned with the smoked flavor, while also deepening the color of the food (Fellows, 2009).

### **Hot Smoking**

Hot smoking exposes the meat to smoke and heat in a controlled environment such as a smoker oven or smokehouse. Hot smoking requires the use of a smoker which generates heat either from a charcoal base, heated element within the smoker or from a stove-top or oven; meat is hot smoked by cooking and flavored with wood smoke simultaneously (Casais, 2011). Similar to cold smoking, the meat may be hung first to develop a pellicle; it is then smoked from 1 hour to as long as 24 hours. Hot smoking usually occurs within the range of 52 to 80 °C (126 to 176 °F) (Myhrvold *et al.*, 2011). When meat is smoked within this temperature range, it is fully cooked, moist, and flavored. If the smoker is allowed to get hotter than 85 °C (185 °F), the meat will shrink excessively, buckle, or even split. Smoking at high temperatures also reduces yield, as both moisture and fat are cooked away.



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### **Liquid Smoke**

Liquid smoke is a product derived from smoke compounds in water which is applied to meat through spraying or dipping (Fellows, 2009). The liquid smoke system helps to control the concentration of smoke being applied, which is used to maintain the bacteriostatic and preservative qualities of the traditional smoking process (Keith, 2015). The use of liquid smoke helps to add flavoring solutions produced from different wood products, under specific pyrolysis conditions and as per extraction protocols aimed at strongly reducing the concentration of Polycyclic aromatic hydrocarbons (Sikorski and Kalakowski, 2010).

Liquid smoke is produced by condensing wood smoke formed by the controlled, minimal oxygen pyrolysis of sawdust or wood chips. Liquid smoke is considered a healthier smoking method, because it reduces the processing time and weight loss of traditional smoldering smoking, and eliminates nitrogen oxides and Polycyclic aromatic hydrocarbons (PAH) levels in smoked meat products, giving much of the desired color and flavor of conventional smoking (Rozum, 2014).

### **Smoke Roasting**

Smoke-roasting refers to the process of combining both roasting and smoking. This smoking method is sometimes referred to as barbecuing or pit-roasting. It may be done in a smoke-roaster, a closed wood-fired oven, or a barbecue pit, any smoker that can reach above 121 °C (250 °F), or in a conventional oven by placing a pan filled with hardwood chips on the floor of the oven so that the chips can smolder and produce a smoke-bath. In North America, this smoking method is commonly referred to as "barbecuing", "pit baking", or "pit roasting". Equipment for smoking bacon, hams and other meat products can be made locally, or smoking kilns can be purchased (Myhrvold *et al.*, 2011).



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### **Types of Meat Smoker**

- (i) Those that produce smoke directly in the base of a smoking chamber;
- (ii) Those that have an external smoke generator that supplies smoke to a smoking chamber. Each type can operate as cold smokers (20 - 32 °C) or hot smokers (70 - 80 °C).

Hardwoods are normally used to generate smoke because they produce the required flavors and color in the smoked meat. Resinous woods, such as fir or spruce, should not be used because they impart an acrid unpleasant flavor (Kubiak, 2013).

Direct smokers can be constructed from bricks or from steel boxes (Figure 1). A simple indirect smoker can be constructed from an old refrigerator by removing the compressor, cutting a vent in the top of the cabinet and fitting an adjustable air vent in the bottom of one side. The smoke generator is a brick or metal cabinet that contains the fire, which has a vent to control the amount of air entering the cabinet and thus restrict the fire to produce smoke. A pipe is connected from the smoke generator to the hole in the side of the refrigerator (Crowe, 2007). Figure 1 is an example of meat smoker oven (Direct Smoker).





**Figure 1:** Meat smoker Photo from Brougham Hall Foods (Direct Smoker)  
Source: Crowe, 2007.

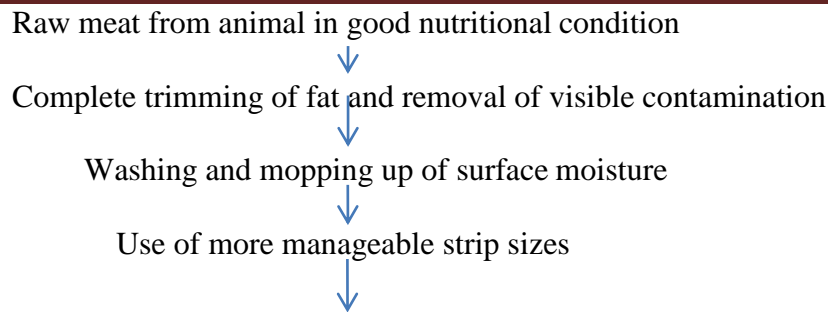
### **Typical Procedure for Smoking Meat**

Meat may be smoked in the raw state or after previous salting, marinating, cooking, or other treatment, which may also be followed by other processing. However, in industrial practice, meat and meat products are usually smoked after salt curing. The pre - treatment of the raw material and the conditions of smoking, mainly the humidity and fat content of the surface layer, the temperature, and density of the smoke, and the duration of the process, affect both the characteristic sensory properties and the shelf life of the products ( Omojowo and Idris 2009 and Egbal *et al.*, 2013). The procedures involved in meat smoking is illustrated in figure 2.



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Generation of smoke from a semi-enclosed environment using hard wood shavings, measured distance between the source of smoke and the meat strips (Smoking takes 2-5 days depending on the size of meat and the desired product).

**Figure 2:** Procedures for smoked meat processing

**Source:** Yusuf *et al.*, 2020.

### SMOKED MEAT IN DEVELOPING COUNTRIES

In Ghana, the Ashanti region located at the central part of Ghana is harboring about 60% of the nation's forest reserves. This undoubtedly makes the region and Ghana one of the major consumers of bush meat since a larger percentage of the wild species reside in these forest reserves. Unfortunately however the obsolete technologies used in processing the meat are very likely to induce Polycyclic Aromatic Hydrocarbons in the meat. Processed meat (bush meat) using smoke from burnt car tyres is raising serious concern because of the adverse effects it may have on consumers. Abu ( 2013 ) carried out analysis on 12 smoked bush meat samples obtained from six local producers within the Kumasi Metropolis to investigate the presence and levels of Polycyclic aromatic hydrocarbons (PAHs) using Gas Chromatography – Mass Spectrometry (GC-MS). The samples were examined for nine of the most carcinogenic Polycyclic aromatic hydrocarbons. The concentrations of naphthalene, 2-methylnaphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene,



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anthracene, fluoranthene and pyrene were: 0.210, 0.379, 0.084, 0.329, 0.066, 0.478, 0.0670.153 and 0.095 respectively. The Polycyclic aromatic hydrocarbons present in the samples were all less than 0.5  $\mu\text{g}/\text{kg}$  on the average of the total contamination profile, with phenanthrene and 2-methylnaphthalene occurring with the highest concentrations (maximum contents of 0.920 and 0.527  $\text{mg}/\text{kg}$  respectively), irrespective of the bush meat type analyzed. Smoked antelope meat was potentially more risky, since total PAHs contents for antelope were generally higher as compared to other smoked bush meat samples.



**Figure 3:** Smoke Roasting Antelope in Ghana  
**Source:** Swensson, 2005.



**Figure 4:** Already Smoked Antelope in Ghana

**Source:** Swensson, 2005.

In Benin, Anihouvi *et al.*, (2013) carried out analysis on the microbiological contamination and quality of Tchachanga, a smoked meat braised product processed at traditional scale in Benin, West Africa. A survey was performed to collect samples of Tchachanga and data related to hygienic conditions of the smoked meat processing environment. A total of 60 samples of Tchachanga including skewers, smoked meat and seasoned wrapped meat were collected from different processing sites in Cotonou, Benin. A follow-up of Tchachanga processing was performed to identify contamination factors of the product. In this respect, samples were collected at certain steps during the processing, and various microorganisms such as coliforms, pathogenic *Staphylococcus* specie and *Salmonella* specie were traced. The number of mesophilic aerobic bacteria in different products ranged between  $6.47 \pm 0.61$  and  $6.93 \pm 0.43$  Log (cfu/g). Total coliforms, faecal coliforms and *Staphylococci* ranged



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from 1.59 to 4.79, 1.00 to 3.2 and 3.49 to 5.2 Log (cfu/g), respectively. No significant differences were observed in the microbial count of different types of Tchachanga investigated, but different processing methods had significant changes in the microbial content of the samples as a result of the processing environments and the ingredients used. The presence of *Salmonella* specie was observed in all products.

“Tchachanga” is a roasted sheep meat in Cotonou, Benin. The main steps of Tchachanga processing are:

- (i) Slaughter,
- (ii) dressing,
- (iii) evisceration,
- (iv) washing,
- (v) cutting,
- (vi) seasoning,
- (vii) braising,
- (viii) smoke roasting and
- (ix) packaging.

The working personnel (the salesman) is mostly uneducated butcher who have received no training in food hygiene, and without sufficient financial resources. The products are therefore exposed to various environmental and microbiological hazards which make the safety of the product questionable (Anihouvi *et al.*, (2013).

In Nigeria, Suya is a spicy, barbecued, smoked roasted meat product. It originated from the Hausa people of northern Nigeria, where rearing of cattle is an important occupation and a major source of livelihood for the people (Inyang *et al.*, 2005). In big cities and small towns, Suya vendors have become very prominent with their grill stands becoming very



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busy from midday until late at night. It is gradually making its way into elite circles where it has become a delicacy served at parties. Suya is prepared basically from boneless meat of Animals (Edema *et al.*, 2008). The preparation process is carried out largely in unhygienic conditions making the risk of contamination very high. The fact that there are sporadic cases of gastroenteritis and symptoms of food infection after consumption of Suya indicate that the product indeed constitutes a food safety risk (Edema *et al.*, 2008). The flow diagram of Suya preparation in Nigeria is shown in Figure 5.

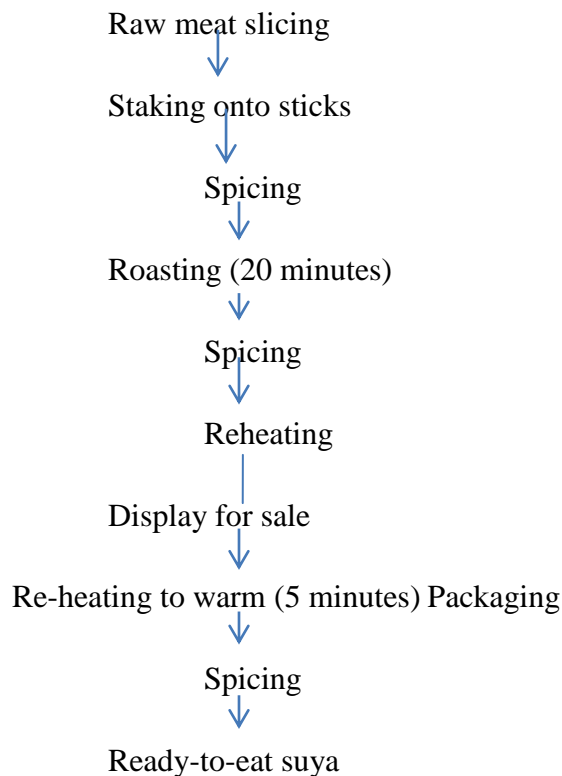


Figure 5: Flow diagram for suya preparation

Source: Edema *et al.*, 2008



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Ready-to-eat Suya samples were collected from six 'Suya spots' in 6 selected cities within south-western Nigeria. On-line process monitoring and sampling during processing was used to identify the Critical Control Points and evaluate microbiological hazards. Microbiological analyses of 144 samples of Suya, processing water, meat processing slabs, utensils, spices and raw meat revealed contamination with potential pathogens such as *Bacillus cereus*, *Staphylococcus aureus*, *salmonellae* and aflatoxigenic molds (*Aspergillus flavus* and *Aspergillus parasiticus*) from utensils and hands of the producers during slicing, staking onto sticks, spicing and holding at ambient temperature ( $28 \pm 2$  °C). Aerobic mesophilic counts were in the order of 105 cfu with the highest value (7.17) observed in the packaging material and the lowest value (1.47) observed in the processing water. The raw meat samples and processing slabs recorded counts in the same range (above 5.5). Occurrence of such organisms in ready-to-eat food constitutes a food safety issue which calls for urgent response in the education of Suya producers on the hazards, Critical Control Points and the importance of personal hygiene and clean environment (Edema *et al.*, 2008).

Umeaku *et al.*, (2018) carried out analysis on nine different samples of ready to-eat meat comprising of three samples of smoked meat bought from hawkers in Ihiala market and three samples bought from hawkers in Danboyi market, Jos. These were analyzed to assess the public health implications of eating vended ready-to-eat meat. Standard microbiological methods were used for isolation. Morphological and biochemical analysis were carried out on discrete colonies using pure cultures to establish their identities. The biochemical tests utilized include: catalase, oxidase, coagulase, citrate utilization, and urease tests. The result of the study revealed that a total of four Genera were isolated, characterized and identified. The isolates include: *Pseudomonas*, *Staphylococcus*, *Bacillus* and *Proteus species*. Meats from all the sources were contaminated with heterotrophic bacteria. Results revealed that ready-to-eat smoked meat were grossly contaminated with bacteria. Aseptic precautions should be employed in the processing, packaging and preservation of ready-to-eat meat to



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avoid outbreak of diseases. The percentage protein for smoked beef is 35% (Nigerian Beef Suya, 2021). Figure 6 and 7 shows hot smoked meat in Nigeria.



**Figure 6:** Hot Smoking Meat in Nigeria

**Source:** Umeaku *et al.*, 2018



**Figure 7:** Hot Smoking Beef in Nigeria

**Source:** Umeaku *et al.*, 2018





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In Kenya, Fonntuma (pounded meat) is a protein rich meat snack comprising of goat or cow cleaned intestines stuffed with cooked small pieces of meat and formed into long coils; sometimes blood is added. Which are then placed in boiling water or soup for 30 to 40 minutes and then roasted over coals on outdoor grills using low to medium heat and turning frequently to dehydrate the meat and give it the sensational smoky taste, then pounded using wooden mortar and pestle until the meat is ground. Then it is deep fried, while stirring continued. Three spoonful of sugar, half tea spoon of salt and grounded cardamom is added, when the product turned golden brown it is removed from fire and cooled overnight or approximately ten hours and stored in closed jug (aluminum/stainless steel or traditional container). The internal temperature should be at least 160 degrees Fahrenheit (Wiens, 2011). Demand for these sausages has resulted in this delicacy's vendors being on the increase. A descriptive study was designed to isolate, characterize and quantify bacteria from Kenyan sausages sold in Nairobi County. A total of hundred (100) Kenyan sausages (62 roasted and 38 non roasted) were conveniently collected from three meat eatery points of West lands, Kangemi slum, and Pangani estates. Five genera of bacteria, namely, *Staphylococcus* spp. at 50.4%, *Bacillus* spp. at 19.5%, *Streptococcus* spp. 9.8%, *Proteus* spp. 2.4%, and *Escherichia coli*. at 1.6%, were isolated from 80 sausage samples. The total aerobic bacterial count range was between  $1.0-9.9 \times 10^1$  and  $1.0-9.9 \times 10^7$  log cfu/g with 37 samples having total aerobic bacterial count of between  $1.0-9.9 \times 10^4$  and  $1.0-9.9 \times 10^7$  log cfu/g. There was no significant difference ( $p > 0.05$ ) in distribution of isolates and total aerobic bacterial count across geographical sites studied among the roasted and non-roasted African sausages (Fonntuma). This study has demonstrated presence of bacteria in Kenyan sausages which are potentially zoonotic to humans (Karoki *et al.*, 2018). In 2018 the percentage protein for Fonntuma was recorded to be 55.8-72.5 (Buke *et al.*, 2018).

Figure 8 shows Fonntuma (pounded meat) preparation in Kenya.



Figure 8: Fonntuma (pounded meat) preparation

Source: Buke *et al.*, 2018.

Bacteriological analyses were conducted on 20 samples for each of ready to eat roasted meats sold by selected food vendors in Lukaya and Najembe highway markets. The three meat products which included chicken, beef and goat meat during dry and wet seasons. International Organization for Standardization (ISO) methods were used in the laboratory to test for presence of coliforms, *Escherichia coli* and *Staphylococcus aureus*. Most samples (68.3%) were contaminated and exceeded the recommended microbial contaminant limit (MCL). *Staphylococcus aureus* was high in beef and chicken where it appeared in 85% of the samples for each product. *Staphylococcus aureus* was also in 75%



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of goat meat samples, *Escherichia coli* was high in chicken (50%), followed by beef (45%) and goat meat (35%) samples. Contamination was slightly higher in the wet season. *Staphylococcus aureus* was the main contaminant. Most ready to eat smoked meats were sold in highway markets were highly contaminated. This result should draw the attention of relevant authorities to ensure that adequate hygienic standards and regular monitoring of the quality of ready to eat smoked meats are improved and practiced to avoid possible foodborne infections (Ananias and Roland, 2017).

### **NUTRITIONAL VARIABILITY, EFFECTS AND SAFETY OF SMOKED MEAT IN DEVELOPING COUNTRIES**

The Nutritional variability in terms of percentage protein from different developing countries varies based on the techniques of preparation and the extent of smoking involved. The effects of smoked meat processing include the accumulation of potentially carcinogenic compounds such as phenanthrene, 2-methylnaphthalene, phenol, aldehydes, indene and naphthalene. Certain microorganisms such as *Salmonella* species, *Pseudomonas* species, *Staphylococcus* species, *Bacillus* species and *Proteus* species, *Streptococcus* species, and *Escherichia coli* may also be in the meats (see Table 1).



**Table 1: Nutritional Variability, Effects and Safety of Smoked Meat in Developing Countries**

Developing Countries	Name of Meat	Smoking Methods	Nutritional /Protein Variability	Effects	Safety
Ghana	Bush meat	Smoke roasting	63%	Polycyclic aromatic, hydrocarbons	Unsafe
Benin	Tchachanga	Smoke roasting	89%	<i>Staphylococcus</i> sp. and <i>Salmonella</i> sp.	Unsafe
Nigeria	Beef	Hot roasting	35%	<i>Pseudomonas</i> sp., <i>Bacillus</i> sp	Unsafe
Kenya	Fonntuma (pounded meat)	Smoke roasting	55.8-72.5%	<i>Staphylococcus</i> sp., <i>Bacillus</i> sp. <i>Proteus</i> sp. , <i>Escherichia coli</i>	Unsafe
Uganda	Roasted Chicken Beef and Goat	Smoke roasting	30%	<i>Staphylococcus aureus</i> , <i>Escherichia coli</i> ,	Unsafe

**Source:** Dave and Ghaly, 2011; Buke *et al*

### Different Sources of Smoked Meat Contamination

This may be biological, chemical or physical. The chemical source of contamination could be from the feed given to the animals while the biological hazards are of concern because the microorganisms or pathogens that are found naturally in the environment or even on live animals (Sofos, 2014).

The occurrence of pathogens on smoked meat can be due to different factors, which include:

- (i) Poor farm animal management,
- (ii) Improper slaughter practices, processing, storage conditions and
- (iii) Lack of meat safety knowledge among meat handlers (Mottier *et al.*, 2000, Marais *et al.*, 2007, Yebra-Pimentel *et al.*, 2015 and Lyon *et al.*, 2018).
- (iv) Carcinogenic components deposited from wood smoke which may include;



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The hazard analysis and critical control point system (HACCP) system recommends that food products should be investigated and traced for their hygiene from the beginning at production to consumption at table (Codex, 2001).

Polycyclic aromatic hydrocarbons (PAHs) are a group of environmental contaminants that emanate from incomplete combustion of fuel or high temperature pyrolysis of fats and oils. It is well known that PAHs occur in curing smoke (Viksna *et al.*, 2008) and that they accumulate on meat being smoked (Andrée *et al.*, 2010), and have been extensively researched into because of their carcinogenicity and teratogenic properties (Anyakora *et al.*, 2006).

To prevent excessive accumulation of PAHs in smoked processed meats, it is recommended to avoid high pyrolysis temperatures and the generation of direct smoking. (King *et al.*, 2002). In modern smoking chambers, the smoke generator is located aside the smoking chamber. Moreover, this separation avoids fat dripping over the fire and minimizes the formation of toxic compounds (Palma, 2008). It is emphasized that the main products of wood pyrolysis are phenols, carbonyls, and organic acids, which are also responsible for the flavor, color, and antimicrobial properties of smoke (Lingbeck *et al.*, 2014). Furthermore, to avoid and control this hazard, a good meat smoking practice is to be established.

### **SAFETY PROTOCOL FOR SMOKED MEAT PROCESSING**

The use of dirty utensils to cut and prepare meat should be avoided. Contaminated water used in washing the meat may play a significant role towards the growth of contaminating microorganisms (Akunjili, 2001 and Anihouvi *et al.*, 2013).

Most times, contamination occurs in meats when it is processed in slaughter houses, because fecal matter from the intestinal tract gets mixed with the meat. Pathogenic



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organisms such as *Salmonella* species, *Staphylococcus aureus*, *Clostridium perfringens* and *Clostridium botulinum* could easily be introduced as a result of improper handling by butchers (Umar *et al.*, 2020).

Heat treatment (thermal treatment) should be practiced while smoking meat since it destroyed most of the bacterial flora that were present on the smoked meat (Kuzelov *et al.*, 2013).

The analysis of trends in microbiological contamination of smoked meat processing should be used to improve theoretically developed Hazard Analysis and Critical Control Point system (HACCP) plans at the level of individual smoked meat production companies.

### CONCLUSION

Smoked meat sold in the market is grossly contaminated with multiplicity of bacteria and polycyclic aromatic hydrocarbons, Portraying that the sanitary quality of the production processes, packaging and handling need urgent improvement. Public health officials should look inward with a view to improving the health of the populace (Public). Sanitary inspectors should be employed at abattoirs and meat handlers should be strongly adhered food safety rules.

### RECOMMENDATIONS

The quality of marketing conditions should be studied by producers for better understanding of changes in microbiological quality of the smoked meat during shelf-life (Aija *et al.*, 2014).

Improper method of preparation can result in quality losses, the use of proper preparation techniques which include manageable stripe thicknesses or sizes, measured distances from the heat source and controlled drying time or period, can produce good quality smoked meat (Yusuf *et al.*, 2020).



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To reduce or eliminate the hazardous effect on the public, hawkers and producers should maintain high personal hygiene habit to avoid cross contamination. Aseptic conditions should be employed in processing, utilization and consumption of the smoked meat. Smoked meat should not be exposed directly to the environment after preparation but should be preserved in a packaged bag in order to limit microbial growth.

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