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RESEARCH ARTICLE

AN OVERVIEW ON FISH SMOKING, NUTRITIONAL QUALITY, WOOD BIPMASS, AND THEIR EFFECTS ON HEALTH

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ABSTRACT

Fishes are susceptible to spoilage which occurred as a results of different factors including high level of temperature, weather, acidity, processing and storage methods and during transportation. This lead to a significant loss during storage of fresh fish samples. Spoilage of fish can be achieved through subjecting the fresh samples to smoking. Cold or hot smoking method to improve shelf-life. The main purpose of this review focused differentiate fish smoking method and the effect of wood biomass on the smoked fish product. The method involved processing and smoking raw fresh fish species with different fuel-wood species to ascertain the quality of the smoked products based on the chemical composition of the smoked fish, composition of the woods biomass and the volatile compounds; both beneficial such as color, aromatic and flavor improvement as well as he harmful effect such as polycyclic aromatic hydrocarbons (HAPs) which poise a severe health effect. Pyrolysis generated from Wood smoke consist of complex mixture of liquids, solid particles and gases (aerosol) due to incomplete burning, pyrolysis or combustion of the wood biomass such as; charcoal, wood chunk, sawdust, wood pellets etc. at an elevated temperatures with reduced oxygen level. Besides the main product of pyrolysis which is 'carbon dioxide and water', wood biomass contain approximately more than 200 different organic compounds identified to induce mild, acute or severe chronic health effects when accumulated in humans body. The nutritional composition of smoked fish samples includes; crude fibre, water content, protein, ash content, amino acids, minerals, phenols and biogenic amines. All the locally available woods species that impart desired colour and flavor also contain minimal level of 0.2 – 5.0 milligram of PAHs per cubic meter of air i.e. (0.2 – 5.0 mg/M^3) are recommended as safe, while at high concentration of 10 and 15 milligrams of PAHs per cubic meter of air is generally considered unsafe and could pose a chronic health challenge.

KEYWORDS

Fish, Woody Biomass, Smoking, Composition, Health Effects

Introduction

Fish are aquatic animals with gills, without fingered limbs which include; Hagfish, Lampreys, Cartilaginous Fishes, Teleost Fishes and different classes / groups. It was recorded that about 95 % of extant global fish species consists of ray-finned fish which belongs to the calls (*Actinopterygii)*, with approximately (99 %) teleost's as reported by Adeogun and Adebisi-Adelani, (2016). They are cold-blooded aquatic animals known as *ectothermic*. This means that they can regulate the body temperature depending on their surrounding temperature, but some active swimming fishes such as great white sharks and tuna, have higher core body temperature (Daniel *et al.,* 2013). Fishes are

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found abundantly in all water bodies nearly everywhere from streams to the deepest ocean depths (Scale, 2018).

Fishes are high-protein, low-fat food that provides many health benefits to humans and also serves as a major source of animal protein and omega 3 fatty acids (Daniel *et al.* 2013; Oyeleye, 2020). They are rich source of essential nutrients needed for supplementing diets of an infants and adults of all age (Oyeleeye, 2020). Currently, fish is considered as one of the major protein sources alongside meat and poultry products (Adeogun and Adebisi-Adelani, 2016) rich in essential fatty acids (EFAs). Fish makes up the majority of dietary protein as well as Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Scales, 2018; Daniel *et al.,* 2013; Adeogun and Adebisi-Adelani, 2016).

Taxonomic Classification of Fishes

Traditional fishes are classified into the following; (i) *Agnathidae* (jawless fishes) these include: Subclasses *Delicates* (breams and lampreys) and *Archaea* (armored jawless fishes) (ii) Class *Chondrichthyes* (chondrichthyes) as reported by (Scale, 2018). Elasmobranchs (sharks and rays) and *Holocephali* (chimeras and extinct related species) (iii) *placoderms* (armorfishes) (iv) *acanthodii* ("spiky sharks", subclass Osteichthyes (teleost fishes) (v) Actinopterygii (ray-finned fishes) and (vi) *Sarcopterygii* (lobed-finned fishes, ancestors of tetrapods).

The taxonomic classification scheme is based on the major classes of fish from evolutionary point of view (Scale, 2018). The above groups are *paraphyletic* in that they belong to a group the jawless fish are the ancestors of the *placodermis*, from which the *teleosts* appeared, the ancestors of the *acanthodii*, the ancestor of the *cartilaginous* fishes and with the introduction of *phylogenetic* nomenclature, the fishes are splits into many more groups as reported by (Oyeleye, 2020).

Nutritional Value of Fresh Fish

Sea food products contained high nutritional value in terms of protein, lipids and essential micronutrients (Lund, 2013). Aquatic animal base diets are rich sources of protein and have lower caloric density with high content of long-chain omega-3 polyunsaturated fatty acids (n-3 LC PUFAs) compared to terrestrial animals (Tacon and Metian, 2013). Historically, one of the main advantage of fish consumption have been attributed to high levels of n-3 low cholesterol poly unsaturated fatty acid (LC PUFA). However, many researchers have proving that other compound nutrients found in fish had tremendous effects on human health as reported by (Khalili and Sampels, 2018). Fish and seafood provides balance amino acid composition and high levels of taurine, choline, vitamins D_3, B_{12}, calcium, phosphorus, iodine, and selenium are found in fish which solely depends on their sources and the environmental factors. In addition, seafood also provides significant amounts of vitamin A, iron, and zinc (Khalili and Sampels, 2018; Lund, 2013) required by the body.

Fish Smoking Process

Fish smoking is a long-term preservation method fish using heat and smoke (Sahubawa and Ustadi, 2014). Fish smoking is a process in which the volatile compounds are injected into the fish by burning woods, allowing the production of a product with specific color, taste, aroma and flavour as well as extending the shelf life. The smoking process involves combination of salting and smoking processes (Andhikawati and Pratiwi, 2021). Smoking is a technique applied for the preservation of fish and fish products; this is achieved by lowering the available water content of the sample by applying heat from a burning wood called aerosol. The heat generated directly inhibits the growth and activities of microorganisms due to the antibacterial effect caused by the wood biomass, and the smoke also coats the outer skin of the fish preventing further contamination when properly stored (Mareta and Awami, 2011).

There are several factors that influence smoking process such as; smoking temperature, humidity, wood type, smoke stream thickness and speed, fish type, and pre-smoking treatment as reported by (Sahubawa and Ustadi, 2014). Smoked fish products can have a shelf life of approximately 6–9 months when properly packaged and stored (Ghazali *et al.,* 2014). According to Berhimpon *et al.,* (2018) smoking tends to produce desirable aroma, flavor and also inhibits microbial growth. In some African countries, such as Indonesia, Nigeria and Ghana etc. there are several types of smoked fish products, such as; *bonito fufu*, *bonito asal*, smoked eel, *sogiri fufu*, catfish jam, smoked catfish and smoked mackerel respectively. For fish to be fully smoked, the smoking process is said to be carried out at an average temperature of (80 - 100 ^{o}C for 3 - 4 h) or at a temperature of (50 - 60 °C for 10–15 h) as reported by (Berhimpon *et al.,* 2018).

Cold Preservation Techniques

Cold smoking is a preservation technique practiced in developed countries of the world where alternative preservation technique / methods such as refrigeration, freezing are readily available. Cold smoking is mainly used to preserve and improve enhance the flavor of fish without altering its nutritional value (Eyo, 2001). Cold smoking is one of the preservation methods that maintains the temperature between 20 - 30 degrees Celsius (68 and 86 ^{o}F), in this temperature range, the fish takes on a smoky flavor but remains relatively moist (Myrvold, 2011; Huong, 2014). Arason *et al.,* (2014) suggest that the relative humidity is kept within the range of 75-85 % during cold smoking after vacuum packing and refrigerated storage, the product is not fully preserved and must be cold smoked (Rørvik, 2000).

Hot Preservation Techniques (Smoking)

Fish is smoked until cooked to obtain product with longer shelf life, as alternative preservation methods such as refrigeration which does not exist in most of the remote fishing areas where most fish processing takes place (Aremu *et al.,* 2013). Hot smoking involves the burning of large amounts of woods which undergoes and incomplete combustion to generate aerosols and other compounds responsible to impact the quality of the smoked fish. Hot - smoked products taste better and last longer (Bede-Ojimadu and Orisakwe, 2020). Hot smoking occurs under a temperature ranged from 52 to 80 °C (126 to 176 °F). Within this temperature range, the fish are fully cooked with pleasant aromatic and color. High temperatures above 80 ^{0}C could lead to excessive shrinkage, buckling, and even cracking which would also reduce yield as well as other essential nutrients loss in the end product (Myrvold, 2011).

Safety of hot smoked fish requires at least 3.5 % water phase salt (WPS) and an internal product temperature of at least 145°F (62.8°C) for at least 30 minutes as a medium to prevents toxin production by *Clostridium botulinum* (Huong, 2014). Additionally, the water activity (aw) of hot-smoked fish products should be less than 0.85 for the product to be stable at room temperature as reported by (Khalili and Sampels, 2018).

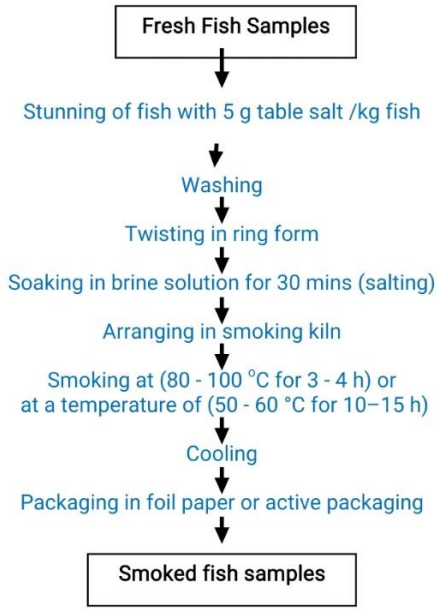
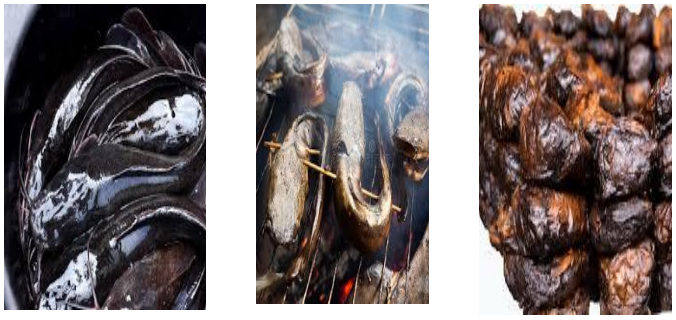


Fig. 1: Flow Chart for fish Smoking process.
Ayeloja *et al.,* (2015)



A. Fresh fish samples B. Traditional method of smoking C. Smoked fish samples

Plate 1.0: Plate showed the fresh fish samples e.g. *Clarias garipinus*, Traditional method of processing (smoking) and end product of smoked fish samples.

Chemical Composition of Smoked Fish

According to Andhikawati and Patiwi (2021), smoking is one of the major preservation methods applied on fish and seafood products. According to Coban and Patir (2013) various studies had been conducted on the role of smoking as a method of preservation. The quality of smoked fish products is influenced by raw materials, smoking method, smoke concentration and the smoking materials (Kjallstrond and Petersson, 2001). Quality indicator for evaluating the shelf life of smoked fish products is derived from the values of TBA, TVB, pH, and biogenic amines consisting of histamine, *putrescine*, *cadaverine*, *tyramine*, and tryptamine compounds (Andhikawati, 2021). The nutritional quality of smoked fish are determined by the percentage of protein, vitamin and mineral content. According to Adeyeye *et al.,* (2018) report that processing of raw materials affects the nutritional content of the final product either positively or negatively due to the loss of nutrients during foods processing. Other way to evaluate the quality of smoked fish products are through quantitative determination of their nutritional composition such as; amino acids, vitamins, and minerals, since amino acids, vitamins, and minerals are usually degraded by heat (Andhikawati and Patiwi, (2021).

Physicochemical Properties of Smoked Fish

In remote fishing areas where major fish processing takes place, the fish are smoked until cooked to obtain a product with a longer shelf-life, where an alternative preservation method such as refrigeration are not available due to poor power supply (Aremu, *et al.,* 2013; Lund, 2013). Smoking results in a significant decrease in protein quality, leading to the loss of available lysine varying from 6 to 33 % at 25 °C and 53 to 56 % at 40 °C resulting in a significant decrease in protein quality of the smoked fish. Lysine is available on the surface of hot-smoked fish, but approximately 12 % is lost in the center during processing (Akinwumi, 2014). Akinwumi (2014) observed that lysine loss was directly proportional to the temperature and smoking time. The loss of lysine is partially due to high temperature effects as a mallard reaction occurred from the smoke reactions, this reaction involves amino acid and sugar compounds. These changes are necessary to give smoked fish a characteristic of a golden color and the loss of other amino acids group such as arginine and histidine decrease the net protein utilization (NPU) observed in smoked fish (Akinwumi, 2014).

During heat treatment, many chemical reactions occurred which includes; decomposition of serine and threonine, dehydration, loss of sulfur through cysteine oxidation of cysteine, methionine, cyclization of glutamate and aspartate as well as threonine. However, a positive effect of heat intensity on the shelf-life of smoked products has been reported by several researchers. According to Ana *et al.*, (2015) carbon dioxides (CO_2) have an important influence on microbial growth and exerts a selective inhibitory effect. Akinwumi (2014) also reports that the effects of smoking and freezing on the nutritional value of African mud catfish (*Clarias gariepinus*) were observed and that the substitutes for smoked fish samples studied showed statistically significant compared with the substitutes for fresh fish samples (Saccani *et al.,* 2013). It was also found that an increase in ash content of smoked fish was due to the loss of moisture, and the significant decrease in moisture content of the smoked fish (Ana, *et al.*, 2015). Pyrolysis breaks down the wood/charcoal components into smoke during combustion giving the fish its unique aroma and improved it taste and color due to the phenolic compounds presents in the wood biomass, nitrites, and formaldehyde contained in the smoke (Saccani *et al.,* 2013; Akinwumi, 2014; Ana *et al.*, 2015).

Effect of Wood Biomass on the Sensory Properties of Smoked Fish

The organoleptic attributes of smoked *Clarias gariepinus* depends on the type of smoking techniques applied, type of fish samples, initial quality of the fresh fish samples and the processing method involved. The removal of water content via application of heat and aerosol during smoking could contributes significantly to the end product of the smoked foods etc. different smoking components have different aerosol concentration on the surface up to the deep layers of the smoked products. Typically, aroma, color as well as taste of the smoked fish products are developed by wood smoke compounds. Whereas, the juiciness, texture and saltiness are determined by raw material properties and processing parameters. Research showed that over 400 different types of compounds was identified in the wood smoke during incompletely combustion process. The type of phenols and their derivatives are considered to be the main factors influencing the taste and aroma of smoked fish (Saccani *et al.* 2013).

Effects of Wood Biomass on the Flavor Characteristics of Smoked Fish

According to Ana *et al.,* (2015) it is evidently accepted that characteristic flavor of wood-biomass cresols is due to the abundant phenolic content present in each wood which also varied from one wood biomass to another. Therefore, the level and quantity of the phenols had been evaluated intensely for an improved flavor in smoked fish and fish products. The taste plays an important role in sensorial attributed conveyed in connection with different volatile compounds. Therefore, distinct compounds may not fully describe the flavor attribute generated during smoking but a collective compound (Ana, *et al.,* 2015). Although an acids, carbonyls and phenols are all important compounds that react during combustion with each other, which are found in lower concentration than the phenols during pyrolysis known as incomplete combustion process (Saccani *et al.,* 2013).

Some phenolic compounds found during smoking is said to be similar with the compounds found in spice, such as eugenol found in nutmeg, marjoram, pepper, cinnamon and cloves. Spices is a carrier of different phenolic compounds found, which are similar to some of the compounds found in smoked fish from various forest woods. The taste of smoked products also depends on the level and number of compounds present (Saccini *et al.,* 2013).

Effect of Smoke on Color Properties

The formation of color in smoked fish samples may be due to combination of low-temperature coloration as well as heat applied resulting in mallard-like Brownian reaction (Saccini *et al.,* 2013; Zdzislaw, *et al.,* 2015). At high temperature, the carbonyl compound formed react with protein in a form of Mallard reaction produce brownish golden color (Pohlmann *et al.,* 2012). This process occurs due to the high presence of phenols present to produce stain and mallard Brownian does not proceed to developed color (Kjallstrand and Petersson, 2001), at temperatures between 80 °C and 90 °C, fuming can occur due to high deposition of phenols, formation of phenolic compounds and browning of mallard re action, were the surface of the product had small particles of darkest spots. There are many spots and the color is dull and dark. (Kjallstrand and Petersson, 2001; Zdzislaw *et al.,* 2015).

The most acceptable color of smoked cat-fish is bright honey gold color, where light brown color is produced by trapping the phenols in the oily surface of the corresponding chemical reaction of the mallard (Ana, *et al.,* 2015). Smoke is a preferred ingredient because it can be described as a natural flavor, and one application is as a roast color enhancer without smoke flavor (FAO, 2017). Smoke produced from starch or wood with very low lignin content contains very little phenol rich in carbons. This compound could be applied as tanning agent against deposits of polycyclic aromatic hydrocarbons, which may have a potential impact (Pohlmann *et al.,* 2012; Ana, *et al.,* 2015).

Effect of Wood Biomass on Microbial Activity of Smoked Fish

Many parts of wood biomass contain antibacterial effects at different level of concentrations used as a natural medium for preservatives during smoking of fish and fish products. Phenolic compounds are some of the most active compounds especially guaiacol cresol, pyro-gallol catechol, and its derivatives. The content, concentration as well as the distribution of phenolic compound and its derivatives in smoked fish depends on the solubility in aqueous-phases product and the smoking conditions. Cat fish smoked for a period of (30 m) at temperature of (22 °C) with smoldering birch wood chunks contains a total of 30–73 µg/g of guaiacol, syringol, trans-*iso-eugenol,* 4-methyl-guaiacol eugenol (Hitzel *et al,* 2012). Whereas, hot-smoked frankfurters had a total guaiacol of 19.6 µg/g as a result of different processing parameters involved up to~57.6 µg/g (Pohlmann *et al.,* 2012). It was reported that the susceptibility of different microbial isolates and their strains to different phenols can vary widely in broths and smoked fish products (Leksono *et al.,* 2020; Hitzel *et al.* 2012).

Wood Smoke

The smoke generated from wood-biomass are made up of complex mixture of (aerosols) such as; liquids, gases and solid particles generated from an incomplete combustion known as pyrolysis and other wood products such as chunks, chips, coal, wood-pellets and saw-dust (Bede-Ojimadu and Orisakwe, 2020). The combustion of wood-biomass needs a sufficient flow of (O_2) which releases CO_2 and water without in the combustion compounds. Meanwhile, incomplete or partial combustion produces smoke in addition to main product of pyrolysis which composed of over 200 different chemical compounds as reported by (Nacher *et al.,* 2007), many of which causes acute or chronic effects when exposed on people which causes severe health effects on the victims. These particulates e.g. (PM 2.5), poise a great health concern as other harmful compound of wood smoke include O_2, CO_2, NO_2, formaldehyde, and (PAHs), which contain carcinogenesis substance such as (Bruce *et al.,* 2000).

Chemical Composition of Wood Smoke

Combustion product (smoke) formed a suspended particulates in liquid, solid particles and gaseous phase combined to form the smoke.

The smoke are generally made of 0.2–0.4 μm particle size (0.05–1 μm) as described by (Guillen *et al.,* 2000) and account for an estimated to about 90% total weight. The complexity of the smoke is identified in the number of compounds found which is said to be approximately 300–400 different volatile compounds present (Simko, 2005). Combustion of fuels produces numerous chemical pollutants in both the smoking and direct drying processes. The volatile compound polycyclic aromatic hydrocarbons (PAHs), includes; nitrogen oxides, dioxins, sulfur oxides and formaldehyde, (source of nitrosamines, etc.). In addition, trace metals present in process of pyrolysis are found (Codex, 2008). The wood usually in form of wood shavings or sawdust (Martin *et al.,* 2010).

The pyrolysis and subsequent oxidation of wood produces various gas that differs in physiochemical properties such as; solubility, chemical properties, boiling point as a characteristic of the smoke from a woos biomass. These consists of H_2O, phenolic group, hydrocarbons, nitrogen oxides, carbonyl group, CO, CO_2, alcohols, esters, and carboxylic, acids. The yields of different ingredients vary depending on the type of woods and the soil composition. The breakdown of the woods when react with oxygen it forms aerosols (FAO, 2017). The dispersed phase and mass fraction of the dispersed phase in an aerosol depends on their chemical conposition and temperature and the droplets enter the dispersed phase (Martin *et al.,* 2010).

The phenol fraction (approximately 240 units) mainly contains phenolic group, 2,5-di-methyl-phenol, guaiacol derivatives, cresol, syringol and their derivative, pyrocatechol, hydro-quinone, hydroxyl di-methoxy-phenyl acetone, resorcinol and pyrogallol contained. The Fraction of phenolic compound depends on the quality of smoke and the temperature of smoking (Roseiro *et al.,* 2012). An increase in temperature causes a decrease in syringol and the 4-methyl-guaiacol, as well as the proportion of trans-iso-eugenol. The phenols occurred as the highest compound yield at the temperature range of 480 to 520 °C. There are also many aldehydes and ketones in smoke. The compound formaldehyde is produced through methanol oxidation as one of the active components of wood carbonisation. The group of carbonyl compounds includes acetaldehyde, benzaldehyde, acetone, and furanones, among others (Roseiro *et al.,* 2012). The percentage acid mainly involved acetone, acetic acid as well as different long and short chain carboxylic acid, keto-carboxylic acids. Alcohol contains a large number of low / average chain molecular weight aliphatic hydrocarbon compounds. Some compounds are also identified from the ester's fractionation of the volatile compounds (Leksono *et al.*, 2020).

Preservative Effect of Wood Smoke

According to Leksono *et al.* (2020), smoked foods are considered as "hurdle technology". Generally, smoking process does not produce a sterile product due to the hygienic condition of the units operations involved and their preservative effects depend on the microbial flora, water activity, pH, heat inactivation of the product such as the antibacterial activity of additives used before smoking, and the antibacterial and antioxidant compounds contained in the product. Smoke composition, packaging barrier properties, and storage temperature (Leksono *et al.* 2020; Aremu *et al.* 2013).

Health Effects of Smoke Generated from Wood

The breakdown of wood biomass is usually carried out in the presence of oxygen and wood smoke produces variety of oxidized compound as liquid or vapor due to organic chemicals. Smoke consists of numerous chemicals, many compound in which contributes negative health effects. E.g. include; nitrogen oxides, formaldehyde, sulfur oxides, Polycyclic aromatic hydrocarbons (PAHs) and dioxins. Heavy metals are also included in the combustion gas. There is considerable evidence that trace metals amount to potential mutagens and carcinogens (Muyela *et al.* 2012). Polycyclic aromatic hydrocarbons contaminate fish with hydrocarbons particularly benzo-[a]-pyrene and nitrosamines, which are theoretically carcinogenic. Consumption of smoked foods high PAH's deposit increases the risk of gastrointestinal cancer as reported by (Muyela *et al.* 2012). Therefore, the presence of PAH residues in food above the Maximum Residue Limit (MRL) of 5.0–8.0 mg/Meq poses a serious threat to public health, raising food safety concerns worldwide. (Muyela *et al.* 2012).

Table 1: Significant Health Effects of Woody Biomass When Smoking

Compound	Example	Sources	Notes	Level of toxicity
Inorganic Gas	*Generated Carbon monoxide*	Pyrolysis	Long range effects	Suffocating end
	Ozone (O_2)	Primary and Secondary products of pyrolysis such as carbon-dioxide and PAH	Exist in wind-direction of smoke and travels over a long distances	Cause Irritation
	Carrier of Nitrogen gasses (N_2)	Temperature variables triggers oxidative rancidity by nitrogen	Reactivity	Irritating substances
	Hundred Hydrocarbons	Incomplete combustion	Some of the means of transport react with organic compound and then form aerosols. Species vary depending on different factors	
	Source of Unsaturated *1,3-butadiene*			Cause irritation, source of cancer and mutagens
	Sources of N-Hexane at saturated level			Neurotoxic and caused irritation
	Many ring (PAHs): e.g. N-Hexane, B *benzo-[a]-pyrene*			It cause Mutagens and cancer cells to replicates
Oxygen enrichment	Organic matter	Incomplete combustion	Part of compounds reacts to form aerosols which vary based on the wood-biomass and the product of pyrolysis	
	Generated Aldehydes such as *formaldehyde and acrolein*,			The effect caused irritation, carcinogens and Mutagens
	Organic compounds such as alcohols and acids e.g.,			Irritation, tetra-togenic

	methanol, acetic acid			
	Activates catechol, cresol and (methyl-phenol)			Caused mutagenic acid, tetra-togenic
Chlorination of organics matter	*Dioxins*	Require Cl compound un the wood smoke		Caused central nervous system (CNS), depression formation
Particles Substances	*Ingestible particulates PM10*	Gasses from incomplete combustion remove ash debris.	Coarse *particles* mainly consist of soil, ash inflammatory and oxidation	causes allergens
	Inflation gasses	Incomplete combustion.	Wood-smoke release particulates compounds	Inflammatory, lead to oxidation stress and allergenic
	Particulates (PM2.5)	*particulates* Condensation	Distance Transport occurred over primary and secondary production	Inflammatory, lead to oxidation stress and allergenic

Source: Naeher *et al.* (2007).

Control Measures of the Effects of Pah Wood Smoke

The presence of PAHs in smoked products are due to environmental pollution and product of pyrolysis which could be prevented by source-related measures such as filtering the smoke from related smoking industries and reducing PAH emissions should be controlled by limiting some factors such as complete combustion process. This could be achieved by design and construction of modernized smoking kiln. Generally, Good Agricultural Practices such as fishing shell-fish from a water contaminated with heavy metals should be discouraged. The research body consist of FAO/WHO Expert Committee regarding safe level of Food carried out a survey on the risk evaluation of PAHs in smoked fish and food additives as reported by (Pagu *et al.,* 2013). The results of the committee suggest that the level of PAHs in smoked fish should be regulated as low as possible in smoking process by selecting right wood biomass with low phenolic compounds and also substituting the incomplete combustion with the production of smoke in a smokehouse, alternatively, done in a smoke house with second hand smoke (aerosol). Eyo (2001) suggests that removing the outer layer of the woods could minimize PAHs, are accumulated more on the outer-surface of the woods (Petridis *et al.* 2012). During smoke production, one can reduce the level of PAH in the final product by regulating the type of smoke generated as complete or incomplete combustion, but can't control PAH content in uncontrolled smoking process. Additionally, storing in polyethylene bags or bottles aid in lowering PAH concentrations as reported by (Guillen *et al.* 2000). In smoke flavor additives are lower than for other smoking processes. When using wood pyrolysis smoking technology, modern systems allow the separation of the smoke chamber and the wood smoke generator (Varlet *et al.,* 2007).

Conclusion

This paper considered relevant overview on fish smoking, nutritional quality, wood biomass, and their effects on health. According to the findings of this review, it was gathered that the reported wood biomass produced desirable color during smoking, while other gave an undesirable color to the end product. The smoking process identifies possible causal and temporal relationships between fish smoking techniques, wood smoke and health effects as presented in table 1 showing above which presents the compounds, examples, sources, means of distribution and level of toxicity were outlined and their possible health effects. Other researchers suggest that exposure to wood smoke has negative effects on overall health when it occurs over long periods of time (Pagu, *et al.* 2013).

As a natural substance, wood smoke contain a number of carcinogenic compounds (PAHs) such as; carbon, benzene, aldehydes and respirable etc. It is well known that compounds release large amounts of known harmful pollutants into the end product smoked. Many of these toxic contaminants found in wood migrate or stick to smoked products. Therefore, there is an urgent need to effectively assess the impact of wood biomass used for fish smoking. The utilization of mangrove wood known as hard wood for fish smoking may be appropriate but should be carried out within a short smoking time or not more than 4 hours, sufficient to obtained smoked product with good shelf-life required. In general, fish that had been smoked using hardwood in a conventional oven for an extended period of time may not be safe to consumption. It is also said that smoked fish with sugarcane bagasse in a traditional oven provide the safest and best way to smoke fish for a short period of time. Relatively low values of polycyclic aromatic hydrocarbons were obtained in the samples smoked with sugarcane bagasse. Compared to mangroves and acacias woods, the carcinogenic and mutagenic risks are lower on average. Mackerel and sardines accumulate more PAHs due to their higher lipid content. High BaP values found suggests an increased risk of carcinogenicity and mutagenicity.

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