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Effects of fuel sources on organoleptic characteristics, polycyclic aromatic hydrocarbon concentration and shelf life of smoked Nile tilapia (*Oreochromis niloticus*)

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Abstract

This study assessed the effect of four different fuel sources on the organoleptic properties, polycyclic aromatic hydrocarbon concentration (PAH) and shelf-life of smoked Nile tilapia (*Oreochromis niloticus*). Dry wood of Gmelina (*Gmelina arborea*), Parkia (*Parkia biglobosa*), Neem (*Azadirachta indica*) and charcoal were obtained around Ladoke Akintola University of Technology, Ogbomoso, Oyo state. Nile tilapia samples were smoked to complete dryness using the four fuel sources. Data were analyzed using descriptive statistics and ANOVA at $p < 0.05$. The organoleptic assessment of smoked fish showed that there were slight differences in sensory score for colour, flavour, texture, taste and overall acceptability due to the difference in fuel source. Fish sample smoked with Gmelina, had the highest score (3.27) for colour while charcoal smoked sample also had highest score of 3.27 for taste. Neem had the highest score of 3.27 and 3.09 for texture and flavour respectively. Overall acceptability of smoked fish samples were 2.73, 2.68, 2.61 and 2.14 for charcoal, Gmelina, Neem and Parkia respectively. Overall acceptability after being kept at room temperature for eight weeks was 2.82, 2.64, 2.46 and 1.46 respectively for charcoal, Gmelina, Neem and Parkia. There was however, no significant difference in the initial and final overall acceptability ($p > 0.05$) after eight (8) weeks of storage. PAHs levels in smoked fish samples produced using the fuel sources was observed. Highest concentrations of $34.91 \pm 0.34 \mu\text{g/kg}$ was found in smoked Nile tilapia produced using Neem while Parkia, Gmelina and charcoal recorded $33.67 \pm 0.52 \mu\text{g/kg}$; $19.57 \pm 0.50 \mu\text{g/kg}$ and $7.54 \pm 0.30 \mu\text{g/kg}$ respectively. Benzo[a]pyrene (BaP) concentrations ($1.37 \pm 0.32 \mu\text{g/kg}$; $1.84 \pm 0.15 \mu\text{g/kg}$; $7.89 \pm 0.59 \mu\text{g/kg}$) for Gmelina, charcoal and Parkia smoked fish samples respectively were below the maximum acceptable limit of $10 \mu\text{g/kg}$ established by the European commission. However, Neem wood with BaP of $11.07 \pm 0.58 \mu\text{g/kg}$ is considered not safe as fuel source for smoking Nile Tilapia.

1. Introduction

Fish is an important source of protein which is critical in the fight against hunger and malnutrition due to its nutritional qualities such as thiamine, riboflavin, vitamin A and D, phosphorus, calcium, iron and high polyunsaturated fatty acids (Areola, 2008). However, fish is one of the most perishable of all staple commodities (Umar *et al.*, 2018). Losses arising from bacteria and breakdown of tissue by enzymes (catalytic spoilage) are enormous hence the need to preserve fish (Ndakatu, *et al.*, 2011). Spoilage in fish is usually accompanied by change in physical characteristics, change in colour, odour, texture, colour of eyes, colour of gills and softness of the muscle (Getu and Misganaw, 2015). The ideal method of fish preservation in developing countries is the traditional smoking method, as this does not require standard infrastructures such as stable electricity as required for freezing method of fish preservation. Fish smoking is one of the oldest methods of preservation (Stolyhwo and Sikorsi, 2005).

The main purpose of smoking fish is not for preservation alone but also to increase its flavour (Visciano *et al.*, 2008). Smoking

of fish products enhances preservation due to dehydration, bactericidal and antioxidant properties of smoke (Miculis *et al.*, 2012). Food can become contaminated during thermal treatments that occur in processes of food preparation and manufacture (drying and smoking) and cooking (roasting, baking, and frying) (Ishizaki *et al.*, 2010). Little is known about the nutritional values of the fish that are smoked with those locally constructed ovens. According to Eyo (2001) most of the works on the nutritional value of smoked has centered on lysine. According to Yola and Timothy (2012), the characteristics of traditionally smoked products are to some extent dependent on the source of the smoke.

Smoking method has significant effect on microbial safety and PAHs concentration of smoked fish (Adeyeye *et al.*, 2016). PAHs are a result of incomplete combustion processes which occur whenever wood, coal or oil are burnt (Kafeelah *et al.*, 2015). It is estimated that nearly 70% of PAHs are consumed in food, including consumption of smoked fish. Of the several hundreds of PAHs, sixteen have been identified to be more harmful than others (Anyakora and Coker, 2006). Benzo (a) pyrene has the highest carcinogenic value than other PAH

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compounds. It contributes 1% to 20% of total carcinogenic effects found in smoked products (**European Commission, 2002**). The choice of fuel is an important aspect to consider in order to avoid potential food contamination, for example, contamination by PAHs differs depending on whether wood, stalks or hay are used (**FAO, 2013**). Studies have shown a relatively good acceptability of charcoal as an alternative to smoking fish due to its effective reduction of polycyclic aromatic hydrocarbons contamination in smoke cured fish products (**Essumang, et al., 2014**). The smoke generated adds flavour, taste, colour (sensory qualities that are desired by consumers) and preservative agents to the fish (**Arason, et al., 2014**). However, little or no information is known of its comparison with other alternatives. This research work helps to enlighten fish processors and home makers on other heat sources that could be used to preserve fish with high nutritional value and most acceptable as the commercially consumed smoke fish at the same time be less strenuous. The aim of this study is to assess polycyclic aromatic hydrocarbon composition, organoleptic quality and shelf-life of Nile Tilapia (*Oreochromis niloticus*) smoked with Gmelina, Parkia, Neem and charcoal.

2. Material and methods

The fish samples were smoked using a charcoal smoking kiln at Ladoke Akintola University of Technology (LAUTECH) Teaching and Research farm and the traditional processing method (with the use of firewood) was carried out at a traditional smoking site in Ogbomoso. The charcoal used for the experiment was obtained at the local market around the experimental site. Three predominant wood species used for the experiment were *Azadirachita indica* (Neem), *Parkia biglobosa* (Parkia) and *Gmelina arborea* (Gmelina) were obtained around the experimental site

2.1 Experimental procedure

One hundred pieces of randomly selected Nile tilapia (*Oreochromis niloticus*) were used for the experiment. The experimental fish were obtained from a reputable farm in Ibadan.

Fish samples were descaled, washed with clean tap water and smoked using four different fuel sources; Gmelina, Parkia, Neem wood and charcoal. The fish were smoked to complete dryness and the time taken for complete dryness was recorded using a digital stopwatch, the smoking temperature for all treatments was maintained between 80°C and 100°C throughout the smoking process for a period of 14 hours after which the samples were kept at room temperature after complete dryness to cool for 1 hour and wrapped in sealable nylon prior to PAH and organoleptic analysis.

2.2 Organoleptic test

The quality of smoked fish samples was subjected to sensory evaluation. The fish samples were evaluated by a group of trained panelists. Preference ranking was done using the method of **Oduor-odote et al. (2010)**. Scoring was done by panelists after each sample was masticated using a 5 point hedonic score for colour (very dark; 1, dark; 2, intermediate; 3, light; 4, very light; 5); flavour (very mild; 1, slightly mild; 2, fairly strong; 3, strong; 4, very strong; 5), texture (very delicate, 1; delicate; 2, medium firm; 3, firm; 4, very firm; 5), taste (very poor; 1, poor; 2, fairly good; 3, good; 4, very good; 5), Overall acceptability (unacceptable: 1; slightly acceptable: 2; moderately acceptable: 3; acceptable: 4; perfectly acceptable: 5).

2.3 Chemical analysis

Smoked fish samples were analyzed to determine total PAHs content and individual PAHs (Benzo[ghi]pyrene, Acenaphthalene, Phenanthrene, Chrysene, Pyrene, Benzo[a]pyrene, Fluoranthene, Naphthalene) according to the method recommended by **Moret and Conte (2002)**.

For determination of the PAH content, 2g quantity of each sample was weighed by means of a digital Mettler weighing balance and put in a 100 ml beaker. 50ml of pentane was added and stirred with a glass rod to homogenize by blending in a Waring blender for 10 mins, to extract all the PAHs and filtered through a Whatman No 42 filter paper. 50ml of isopropyl alcohol was added to the filtrate and put in a 250 ml separating funnel, stoppered and shaken to cause a separation of the pentane layer. This extraction was repeated twice and all pentane extracts were combined in the second 250 ml separating funnel and later transferred to a 50ml volumetric flask which was made up to mark with pentane.

2.4 Statistical Analysis

Data collected were subjected to one way analysis of variance (ANOVA) using computer package of **SAS (2001)** and mean were equated by Duncan multiple range test.

2.5 Shelf -Life Analysis

Smoked fish samples were stored separately for a period of 8 weeks at room temperature to determine differences in sensory qualities of the smoked fish after the 8 weeks of storage.

3. Results

3.1 Sensory Analysis

Sensory characteristics scores for colour, flavour, texture, taste and overall acceptability for Nile Tilapia (*O. niloticus*) using different smoke sources was obtained after assessment by the taste panel. Overall acceptability was estimated from the mean scores recorded from the organoleptic properties of the smoked fish samples using different smoke sources. The score for colour for Gmelina smoked Nile tilapia was 3.27 with brighter colour while charcoal, Parkia and Neem smoked samples had scores of 1.73, 1.64 and 1.46 respectively with dark appearances. Nile Tilapia samples smoked from Neem wood had highest score for flavour (3.09) and was judged to have strong flavour while the lowest of 2.46 was recorded in Parkia and considered to be fairly strong in flavour. Neem also recorded highest score of 3.55 in texture and was followed by charcoal (3.36) and were judged to be of firm texture. Gmelina was least with 2.18. Parkia smoked sample had lowest score (1.82) for taste and was judged to be poor while charcoal recorded highest score of 3.27 in taste and was judged to be good. However, overall acceptability for all smoked fish samples from highest to the lowest were 2.73, 2.68, 2.61 and 2.14 respectively for charcoal, Gmelina, Neem and Parkia and they were all judged to be moderately acceptable as shown in Table 1.

3.2 Polycyclic Aromatic Hydrocarbons

Concentrations of polycyclic hydrocarbon (PAH) present in smoked Nile tilapia (*Oreochromis niloticus*) using different smoke sources is shown in Table 2. Nile tilapia smoked with Neem and Parkia woods had higher concentration of Benzo (ghi) pyrene (BghiP) (3.14 µg/kg; 2.69 µg/kg) respectively while Gmelina and charcoal had lower Benzo (ghi) pyrene (0.48 µg/kg; 1.00 µg/kg) respectively. Acenaphthalene values present in Nile tilapia smoked with Neem wood (10.92 µg/kg) was higher than concentrations present in samples smoked using

Parkia, Gmelina and Charcoal (7.02 µg/kg, 1.63 µg/kg, 1.18 µg/kg) respectively. Phenanthrene value present in smoked Nile tilapia samples produced using Neem wood was higher (7.19 µg/kg) compared to Parkia, Gmelina and charcoal. Charcoal and Gmelina smoked Nile tilapia had the least value of Phenanthrene with 1.14 µg/kg and 0.55 µg/kg respectively.

Also, smoked Nile tilapia produced with Charcoal and Gmelina had the least value for pyrene (2.06 µg/kg and 0.67 µg/kg), BaP (1.84 µg/kg and 1.37 µg/kg), Fluoranthene (1.40 µg/kg and 0.81 µg/kg). However, fish samples smoked with Neem wood had higher value of Naphthalene (13.21 µg/kg) compared to Parkia, charcoal and Gmelina (9.63 µg/kg, 2.67 µg/kg and 2.24 µg/kg). Total concentrations of PAHs was highest (34.91±1.34 µg/kg) in fish samples produced using Neem as smoke source and was followed by Parkia (33.67±0.52 µg/kg), charcoal (19.57±0.50 µg/kg) and Gmelina (7.54±0.30 µg/kg) respectively. The values recorded for Benzo(a)pyrene considered to be the most carcinogenic of all PAHs were 1.37±0.32 µg/kg; 7.89±0.59 µg/kg; 11.07±0.58 µg/kg and 1.84±0.15 µg/kg for Gmelina, Parkia, Neem and charcoal respectively.

3.3 Organoleptic assessment of Shelf-life

Sensory score for colour, flavour, texture, taste and overall acceptability for Nile tilapia (*O. niloticus*) using different smoke sources was obtained after 8 weeks as shown in Table 3. The mean score obtained for each of the sensory properties was used to ascertain the shelf-life of the smoked fish samples. There is significant reduction in Gmelina score for colour from 3.27 to 2.27 after 8weeks while there was increase score for charcoal and Neem (2.46; 1.91) from the initial score of 1.73 and 1.46 respectively. There was a reduction in the overall acceptability score of 2.64; 1.46 and 2.46 for Gmelina, Parkia and Neem smoked samples respectively after 8weeks. Charcoal smoked fish samples recorded an increase in overall acceptability score from 2.73±0.76 to 2.82±0.22. Parkia had the lowest score for overall acceptability (1.46±0.51) and was judged unacceptable and therefore not fit for consumption. However, there was no significant difference in the initial and final overall acceptability ($p>0.05$) after eight (8) weeks of storage as shown in Table 4.

Table 1 Mean Sensory Scores for smoked Nile Tilapia (*Oreochromis niloticus*) using different fuel sources

Parameters	Fuel sources							
	Gmelina		Parkia		Neem		Charcoal	
Colour	3.27	Light	1.64	Dark	1.46	Very dark	1.73	Dark
Flavour	2.82	Fairly strong	2.46	Fairly strong	3.09	Strong	2.55	Fairly strong
Texture	2.18	Medium firm	2.64	Medium firm	3.55	Firm	3.36	Firm
Taste	2.46	Fairly good	1.82	Poor	2.36	Fairly good	3.27	Good
Overall	2.68	Moderately	2.14	Moderately	2.61	Moderately	2.73	Moderately
Acceptability		Acceptable		Acceptable		Acceptable		Acceptable

GT; Gmelina smoked Nile tilapia, PT; Parkia smoked Nile tilapia, NT; Neem smoked Nile tilapia, CT; Charcoal smoked Nile tilapia. All judgments were based on hedonic scale of preference

Table 2 Concentrations of polycyclic hydrocarbon (PAH) present in smoked Nile tilapia (*Oreochromis niloticus*)

	GT	PT	NT	CT	SEM
Benzo(ghi)pyrene (µg/kg)	0.48±0.06 ^b	2.69±0.17 ^c	3.14±0.091 ^a	1.00±0.58 ^b	0.36
Acenaphthalene (µg/kg)	1.18±0.16 ^c	7.02±0.57 ^b	10.92±0.44 ^a	1.63±0.39 ^c	1.23
Phenanthrene (µg/kg)	0.55±0.49 ^c	4.26±0.50 ^b	7.19±0.55 ^a	1.14±0.90 ^c	0.82
Chrysene (µg/kg)	1.24±0.12 ^c	7.36±0.68 ^b	11.75±0.40 ^a	1.71±0.16 ^c	1.32
Pyrene (µg/kg)	0.67±0.06 ^c	4.76±0.14 ^b	6.81±6.81 ^a	2.06±0.03 ^c	0.72
Benzo(a)pyrene (µg/kg)	1.37±0.32 ^c	7.89±0.59 ^b	11.07±0.58 ^a	1.84±0.15 ^c	1.25
Fluoranthene (µg/kg)	0.81±0.27 ^c	6.89±0.49 ^b	8.78±0.22 ^a	1.40±0.20 ^c	1.04
Naphthalene (µg/kg)	2.24±0.18 ^c	9.63±0.48 ^b	13.21±0.40 ^a	2.67±0.33 ^c	1.41
ΣPAHs(µg/kg)	7.54±0.30 ^c	33.67±0.52 ^a	34.91±1.34 ^a	19.57±0.50 ^b	3.40

GT: Gmelina smoked fish, PT; Parkia smoked fish, NT; Neem smoked fish, CT; Charcoal smoked fish. Means with different numbers (letters) in the same row (column) are significantly different ($P<0.05$). Values are mean± S.E.M for three replicates

Table 3 Mean sensory scores for taste, flavour, texture, taste and acceptability of smoked Nile tilapia using different fuel sources at 8 weeks

Parameters	Fuel sources							
	GT		PT		NT		Charcoal	
Colour	2.27	Intermediate	1.55	Dark	1.91	Dark	2.46	Intermediate
Flavour	2.46	Fairly strong	2.46	Fairly strong	2.73	Fairly strong	2.73	Fairly strong
Texture	3.27	Firm	2.82	Medium firm	2.18	Medium firm	2.36	Medium firm
Taste	2.91	Fairly good	1.91	Poor	2.55	Fairly good	2.82	Fairly good
Overall	2.64	Moderately	1.46	Unacceptable	2.46	Moderately	2.82	Moderately
Acceptability		acceptable				Acceptable		acceptable

GT; Gmelina smoked Nile tilapia, PT; Parkia smoked Nile tilapia, NT; Neem smoked Nile tilapia, CT; Charcoal smoked Nile tilapia. All judgments were based on hedonic scale

Table 4 T-test showing difference in initial and final overall acceptability of Nile Tilapia after 8 weeks of storage

	N	Mean	Standard deviation	T	df	Sig.
Initial overall acceptability	20	2.5410	0.59363	1.024	38	0.827
Overall acceptability after 8weeks	20	2.3570	0.54180	1.024	37.687	0.827

4. Discussion

Nile tilapia (*O. niloticus*) produced using Gmelina recorded the highest score for colour and with appealing bright colour. **Davies et al. (2012)** opined that colour is one of the major parameters of food that can easily attract consumers and also play a significant role in food acceptability. The best appearance of smoked fish according to **Leksono et al. (2020)** and **Obodai et al. (2009)** is characterized by its surface colour which is golden brown. Gmelina wood generated a high density smoke during combustion, this contributes to the desirable golden brown colour formation of the samples. Low density smoke does not form the desirable golden colour, and the odour of smoke in the finished fish is weak (**Belichovska et al., 2019**). Sensory score of other organoleptic properties of smoked fish samples of flavour, texture and taste varies from one smoke source to the other. This is in agreement with Oduor-Odote et al. 2010 who posited that organoleptic properties of smoked foods are decisively influenced by composition of the smoke and nature of wood involved. This was also buttressed by **Rinto et al., (2023)** in their recent work where the use of different types of firewood affected the appearance and taste of skipjack smoked fish. Sensory evaluation after 8weeks to assess the shelflife of the smoked fish samples showed considerable reduction in the mean value for overall acceptability.

This is in agreement with **Arason et al. (2014)** who stated that smoking can affect the weight, pH, protein structure, flavour and texture of fish muscle. The decrease in pH could result in muscle proteins having reduced net surface charge thereby causing proteins to partially denature, decreasing water holding capacity and influencing the microbiota in the muscle (**Teixeira, et al., 2014,; Bowker and Zhuang, 2015**).

The significant difference in the concentration of total PAHs in the smoked Nile tilapia samples produced using Gmelina, Parkia, Neem and charcoal is in agreement with **Garcia-Falcon and Simal-Gandara, (2005)** who posited that the levels of PAH in smoke depends on smoke source, temperature, flame intensity in flame combustion and particulate material generated during combustion. Highest level of PAHs was found to be present in samples produced with Neem wood.

However, Benzo[a]pyrene concentrations for Gmelina, charcoal and Parkia smoked fish samples ($1.37 \pm 0.32 \mu\text{g/kg}$; $1.84 \pm 0.15 \mu\text{g/kg}$; $7.89 \pm 0.59 \mu\text{g/kg}$) were respectively below the maximum

acceptable limit of $10 \mu\text{g/kg}$ established by the European commission (European commission, 2002).

5. Conclusion

Results obtained from this study revealed that Nile tilapia smoked using Gmelina and Charcoal as smoke material had longer duration of storage, improved sensory qualities and higher overall acceptability. The PAHs levels in smoked fish samples were found to vary with the various smoke sources. Continuous consumption of smoked Nile tilapia produced using Gmelina wood and charcoal does not pose elevated health risks to consumers. However, Neem and Parkia smoked Nile tilapia are not advisable and considered unfit for smoking.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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