Consumer awareness of polycyclic aromatic hydrocarbon (PAHS) contaminants in smoked fish and factors influencing smoked fish consumption in Ado-Odo/Ota Local Government area of Ogun State

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ABSTRACT

Fish has long been recognized as a healthy food which provides the body with excellent nutritional value. Due to its perishable nature, fish are commonly processed to increase its shelf life. In Nigeria, fish smoking is the commonest method of fish preservation which involves the use of traditional smoking kilns which are poorly constructed and lack mechanisms for heat control often resulting in the production of polycyclic aromatic hydrocarbons (PAHs) in smoked fish. The study assessed consumers' awareness of PAHs and other contaminants in smoked fish and determined the factors influencing smoked fish consumption among the respondents in the study area. A two-stage sampling technique was employed to select 105 respondents from the study area. Data was obtained with the aid of a well-structured questionnaire. The analytic techniques used for data analysis were descriptive statistics and binary logit regression model. Findings revealed that most of the respondents were females, married, having a mean age of 39 years with formal level education. Findings also revealed that most of the consumers had knowledge of the presence of PAHs in smoked fish which are injurious to health. Furthermore, age, gender, income, marital status, taste, household size, education and aroma were found to significantly influence smoked fish consumption at 1%, 5% and 10%, respectively. The study therefore concludes that awareness of polycyclic aromatic hydrocarbons (PAHs) and other micro-organisms in smoked fish was low among the respondents in the study area.

Introduction

Fish and fishery products have long been recognized as healthy foods with excellent nutritional value, providing high-quality protein, minerals, vitamins, essential fatty acids and trace elements. It is widely consumed in many parts of the world by humans due to its high content of good protein which is characterized by an excellent amino acid composition and easy digestibility (Adel *et al.,* 2019). Fish is an

important dietary component of people around the world and represents a relatively cheap and accessible source of high-quality protein for poorer households (Adeyeye *et al.,* 2015). The volume of global fish production amounted to 184.6 million metric tons in 2022, up from 178.1 million metric tons in 2021. Fish is one of the most widely consumed foods in the world, and it is only becoming more popular over time (Shahbandeh, 2023).

Aquaculture plays a key part in the Nigerian economy, as it does in the economies of other African nations, in terms of job creation and income generation (Mulokozi *et al.,* 2020). This is especially true in fishermen's communities that rely on the sale of their catch for a living. Despite the fact that aquaculture is the fastest-growing food-producing sector in the world, its contribution to Nigeria's overall fish output remains negligible (Issa *et al.,* 2022). According to (Elfredah, 2022), Nigeria produces over one million metric tons of fish yearly, but only about 10 percent of that amount is exported. Meanwhile, the country consumes roughly 3.6 million metric tons of fish each year. The production of fish makes it the most traded foodstuff in the world but also poses a conservation problem mainly in developing countries (FAO, 2020). Indeed, since fish is a highly perishable commodity, special care must be taken at the time of capture or harvest and throughout the supply chain in order to preserve its quality and nutritional attributes, avoid the risk of contamination, and limit loss and waste (Pigott, 2016; Kruijssen *et al.,* 2020). According to the (FAO, 2020), it is estimated that 35% of the global harvest is either lost or wasted every year. These losses in quantity and quality are due to the inefficiency of value chains, especially for sub-Saharan countries. To limit these losses, preservation methods exist such as freezing, refrigeration, salting, drying, and especially smoking (Alabi *et al.,* 2020).

Fish smoking is the principal fish processing technique in Nigeria (Ayeola *et al.,* 2011; Sakyi *et al.,* 2019; Alabi *et al.,* 2020). Smoking involves heat application to remove water and inhibit bacterial and enzymatic action on fish. Fishes that are smoked have a great sensory characteristic such as good taste, flavour and texture and are highly enjoyed in diets (Puke & Galoburda, 2020). Several studies have revealed that smoked fish processors in Nigeria employ traditional techniques of fish processing which has been in existence for several decades such as cylindrical metal or oil-drum oven (full or half drum), mud oven, box oven, cut-up barrels and brick kiln (George *et al.,* 2014; Olaoye *et al.,* 2015; Odediran & Ojebiyi, 2017; Alabi *et al.,* 2020). However, the traditional fish smoking kilns are poorly constructed and lack mechanisms for the control of smoke and heat production, all of which affect the efficiency of smoking and the quality of the final products.

Polycyclic aromatic hydrocarbons (PAHs) are widespread environmental contaminants representing an important group of carcinogens that have been detected in smoked fish. The health effects resulting from too much of PAH exposure include growth retardation, low birth weight, small head circumference, low intelligence quotient, damaged deoxyribonucleic acid in unborn children and the disruption of endocrine systems, such as estrogen, thyroid and steroids (Shen *et al.,* 2008; Essumang *et al.,* 2012). Evidence has also revealed that microorganisms such as *Staphylococcus aureus* and *Eschericia coli* associated with smoked fish pose a great threat to the populace. This is as a result of the

transfer of the microorganisms which attack the immune system of the consumer, usually man, thereby, giving room for the invasion of disease (Adelaja *et al.,* 2013).

The bacteria group of *Staphylococcus aureus* may cause superficial and systemic infections such as boil, impetigo and folliculitis while more serious and more common infections could be pneumonia, bacteria and other infections of the bones and wounds. A recent study has also revealed that *Eschericia coli* usually cause diarrhea, kidney damage as well as uncomplicated community-acquired urinary tract infections (Ryan, 2023). Furthermore, certain heavy metals such as lead, cadmium, mercury and chromium have also been detected in smoked fish and have been recognized to be potentially toxic to man (Adeyeye *et al.,* 2016). The health effects from exposure to chromium are dermatitis, skin inflammation, chronic allergic reaction, an asthma-like condition in the lungs and respiratory tract, lung cancer, and weak carcinogenic infections. Polycyclic aromatic hydrocarbons (PAHs) are formed by incomplete combustion processes which occur whenever wood, coal, or oil are burnt. The incomplete wood combustion during smoking can produce considerable amounts of PAHs which can penetrate through the surface of products such as meat or fish (Jira *et al.,* 2006).

In Nigeria, smoked fish products are the most common form of fish product for consumption. Out of the total of 194,000 metric tons of dried fish produced, about 61% of it is smoked (Adeyeye *et al.,* 2015). The high levels of consumption of smoked fish is worrisome due to the implications for food security and food safety (Alabi *et al.,* 2020). Against this background, it therefore becomes imperative to assess the awareness of consumers of PAHs contaminants in smoked fish in Ado-Odo/Ota Local Government Area of Ogun State. Specifically, this study aims to assess the awareness of consumers about PAHs in smoked fish, identify the consumers' sources of information about PAHs, and assess the consumer's perception of smoked fish, as well as determine the factors influencing its consumption in the study area. The outcome of the study will provide baseline information to future researchers who wish to conduct further research in this area.

Materials and Methods

Study area

The study area was Ado-Odo/Ota Local Government Area of Ogun State. It is one of the 20 Local Government Areas of Ogun State, Nigeria. The area is located within latitude 6°41′00″N and longitude 3°41′00″E. It has an area of 878 km² and a population of 526,565 at the 2006 census. Ado-Odo/Ota came into existence on May 19, 1989, following the merging of Ota, part of the defunct Ifo/Ota Local Government with Ado-Odo/Igbesa Areas of the Yewa South Local Government and borders on Metropolitan Lagos.

The Local Government Area is the second largest in Ogun State which is made up of ten wards. It is a tropical area and has two seasons: the rainy and dry seasons. The rainy season is from April to October; average daytime temperature is about 32^{0}C and relative humidity can be as high as 95%, being primarily agrarian in nature. The Local Government produces cash and food crops such as cocoa, cotton, cassava, rice, maize, and many others. The settlements and the wetlands cover an estimated area of 1,543 km², which is about seven percent of the total landmass of Ogun

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State. The people almost exclusively engage in fishing, crop farming, craft-making, trading and hunting. There is also a preponderance of big markets where smoked fish is sold.
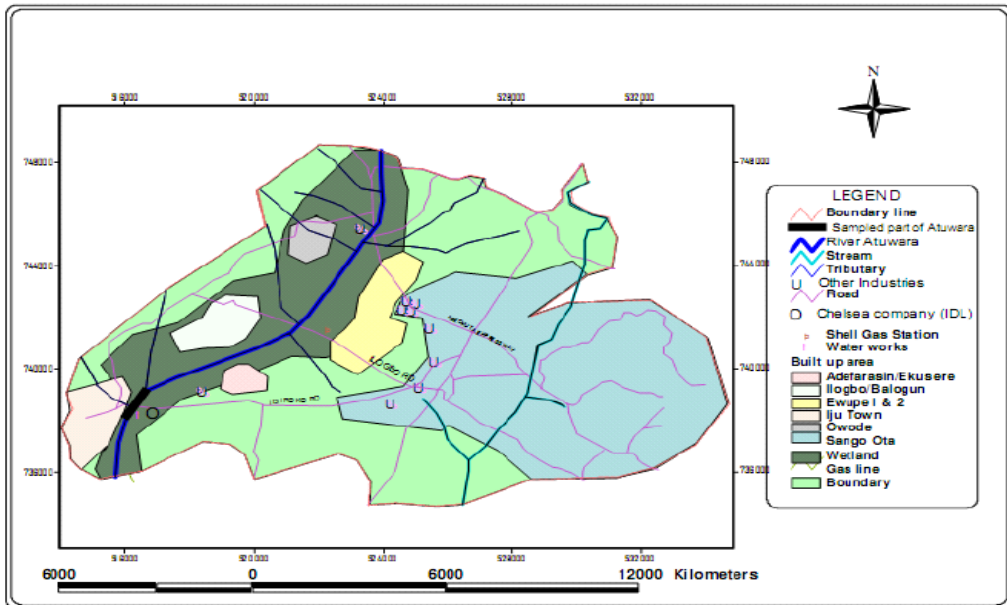

Fig 1: The map of Ado-Odo Ota Local Government Area, Ogun State, Nigeria. Source: Omole & Longe (2014)

Sampling size and sampling procedure
A two-stage sampling technique was used to gather information from the respondents with the use of a well-structured questionnaire. The first stage was purposive selection of seven communities within the Local Government and these were: Ado-Odo, Agbara, Igbesa, Iju-Ota, Itele, Owode and Sango-Ota due to high rate of smoked fish consumers based on a pilot survey, while the second stage was also the random selection of fifteen (15) households from each of the selected communities thereby producing a sample size of 105 households.

Method of data collection
The study mainly used primary data. Data on respondent's socio-economic characteristics,

their awareness of PAHs and other contaminants in smoked fish, their perceptions about smoked fish, as well as sources of consumer's information about PAHs and other contaminants in smoked fish were obtained through a well-structured questionnaire.

Method of data analysis
Data were analyzed using both descriptive (percentages, frequency distribution tables, mean standard deviation) and binary logit regression model. The statistical tool used for the analysis is STATA software, version 12.

Binary logit regression model
The binary logit regression was used to estimate the factors influencing the consumption of

smoked fish in the study area. The explanatory variables in the model were: age, gender, monthly household income, household size, marital status, educational qualification, primary occupation, taste, aroma and rich source of nutrient. The logit model (Greene, 2000) is designated explicitly as:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots + \beta_7 X_7 + \beta_8 X_8 + \beta_{10} X_{10} + e_i$$

Where Y = Consumption (1, if household consume smoked fish; 0 otherwise)
β_0 = Constant
$\beta_1 - \beta_9$ = Regression parameter estimates
e_i = Sample error term
X_1 = Age of the household head (Years);
X_2 = Gender (female = 1, male = 0);
X_3 = Monthly household income (Naira);
X_4 = Household size (Number of persons);
X_5 = Marital status (1= married, 0 = otherwise);
X_6 = Educational level of household head (Number of years spent in school);
X_7 = Primary occupation (1 = civil service, 0 = otherwise);
X_8 = Taste (1 if the consumer strongly agrees, otherwise = 0)
X_9 = Aroma (1 if the consumer strongly agrees, otherwise = 0)
X_{10} = Rich source of nutrient (1 if consumer strongly agrees, otherwise = 0)

Results and Discussion

TABLE 1
Distribution of respondents by their socio-economics characteristics

Variables	Frequency	Percentage	Mean±SD
Age (years)			
< 20	4	3.8	39.5±15.7
21-30	31	29.5	
31-40	30	28.6	
41-50	13	12.4	
51-60	14	13.3	
> 60	13	12.4	
Educational status			
No Formal Education	13	12.4	10.1±5.8
Primary	17	16.2	
Secondary	25	23.8	
NCE/OND	17	16.2	
HND/BSC	22	21.0	
Post Graduate	11	10.5	
Household size (number of person)			
1-3	36	34.3	4.2±1.7

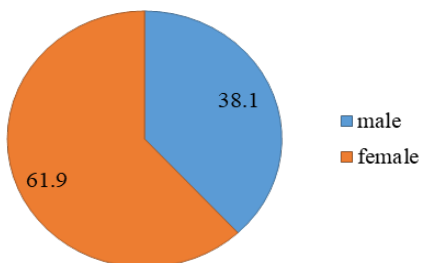|			
4-6	62	59.0	
7-9	7	6.7	
Income (naira)/month			
< 10,000	31	29.5	₦90,272.0±59,457.1
10,001-20,000	2	1.9	
20,001-30,000	9	8.6	
30,001-40,000	16	15.2	
> 50,000	47	44.8	
Religion			
Christian	46	43.8	
Muslim	50	47.6	
Traditional	9	8.6	
Main Occupation			
Civil Service	16	15.2	
Trading/Commerce	50	47.6	
Farming	7	6.7	
Others	32	30.5	

Source: Field survey, 2022

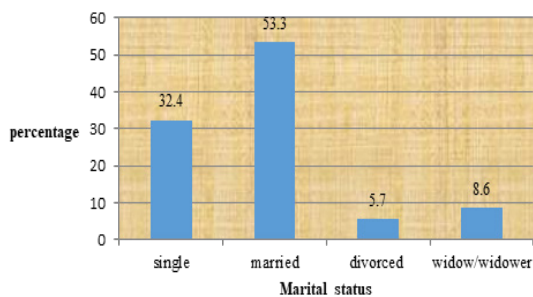Fig 2: Distribution of the respondents by gender

Fig 3: Distribution of the respondents by their marital status

Socio-economic characteristics of the smoked fish consumers

The result of the socio-economic characteristics of the smoked fish consumers in the study area as revealed in Table 1 shows that a majority (62%) of the smoked fish consumers had a mean age of 39 years. This implies that most of the smoked fish consumers in the study area were young and within their productive age. However, prolonged consumption of smoked fish may lead to ill health later on in life. Findings have confirmed that consuming smoked fish contaminated with PAHs and other micro-organisms such as *Eschericia coli* increases the risks of gastrointestinal cancers, diarrhea, kidney damage as well as uncomplicated community-acquired urinary tract infections (Ryan, 2023).

Furthermore, a majority (87.6%) of respondents had one form of formal education or the other with 16.2% having primary education, 23.8% having secondary education and 47.2% having a tertiary education. This could imply that education influences the consumption of

smoked fish in the study area as a result of the knowledge about the nutritional benefits of smoked fish. This finding is consistent with that of (Agbontale *et al.,* 2020), who noted that an increase in the level of education had a positive influence on fish consumption. Results in Table 1 also revealed that 34.3%, 59.0%, and 6.7% of the respondents had household sizes of 1-3, 4-6, and 7-9 persons respectively with a mean household size of about four persons. The mean income of the households was ₦90, 272.0 per month. This shows that the monthly income of most of the respondents in the study area was low. About 43.8% of the respondents were Christians while 47.6% were Muslims with only 47.6% of the respondents having businesses as their major occupation.

The results in Figure 2 also revealed that most (61.9%) of the respondents were females and approximately 38.1% were male.

This implies that there were more females who consumed smoked fish in the study area than men. This could be due to the fact that women generally are the purchasers of food items in most households and as such may prefer to buy smoked fish because of its taste and aroma. However, this contrasts with the findings of (Adeola *et al.,* 2016) who reported that there were more male consumers of smoked catfish than women. As regards the marital status of the respondents, figure 3 showed that about 53.3% of the respondents consuming smoked fish in the study area were married. This could be as a result of the fact that smoked fish is more affordable to families who have financial commitment compared to singles with little or no responsibilities. This result collaborates with the findings of (Adeola *et al.,* 2016) who observed that smoked fish is more popular among married people.

TABLE 2

Distribution of respondents by their awareness of PAHs and other contaminants in smoke fish

Awareness	Yes(%)	No(%)
Polycyclic aromatic hydrocarbons (PAHs) are widespread environmental contaminants representing an important group of carcinogens that have been detected in smoked fish.	35.2	64.8
Staphylococcus aureus and *Eschericia* coli are among the commonest micro-organisms associated with smoked fish.	45.7	54.3
Staphylococcus aureusmay cause superficial and systemic infections such as boil, impetigo, and folliculitis in man.	45.7	54.3
Consuming smoked fish for long can cause more serious infections which could lead to pneumonia and other infections of the bones and wounds.	41.0	59.0
Eschericia coli found in smoked fish can cause diarrhea and kidney damage as well as urinary tract infections	41.0	59.0
Certain heavy metals such as lead, cadmium, mercury, and chromium have been detected in smoked fish which are toxic to human health	51.4	48.6
The health effects of exposure to chromium are dermatitis, skin inflammation, chronic allergic reactions, etc.	51.4	48.6
Smoked fish possess microorganisms that pose a great threat to the immune system of man	35.2	64.8
The health effects resulting from too much PAHs exposure include growth retardation, low birth weight, small head circumference, low IQ, damaged DNA in an unborn child, etc.	42.9	57.1

Source: Field survey, 2022

Awareness of consumers on PAHs and other contaminants in smoked fish

The awareness of consumers on the health effects of consuming smoked fish is presented in Table 2. The result indicated that awareness of the presence of polycyclic aromatic hydrocarbons (PAHs), microorganisms such as bacteria, *Staphylococcus aureus*, *Eschericia coli* and certain heavy metals such as; lead, cadmium, mercury and chromium found in smoked fish was low. As regards PAHs, only 35.2% of the respondents were aware that smoked fish contains PAHs which are carcinogenic to man, 41% of the respondents were also aware that the presence of micro-organisms such as *Staphylococcus aureus* and *Eschericia coli* detected in smoked fish can cause diarrhea, boil, impetigo, folliculitis, kidney damage as well as urinary tract infections.

Similarly, only 41% of the respondents were aware that consuming smoked fish for long can cause serious infections which could lead to pneumonia and infections of the bones and wounds. Thus, the low level of awareness of the health effects associated with consuming smoked fish is worrisome and could be an indication of inadequate diffusion of information by extension agents and other relevant stakeholders to the fish consumers in the study area. This finding is synonymous with the recent research conducted in Senegal by Food Enterprise Solutions (FES, 2021) which reported that awareness of PAHs among the consumers of smoked fish was very low, with less than 5% of all respondents knowing what PAHs were and their associated risks.

TABLE 3

Distribution of respondents by their perception of smoked fish

Perception Statements	SD(-1)	D (0.5)	U (0)	A (0.5)	SA (1)	Mean
Smoked fish gives a better aroma to food.	1.9	3.8	1.9	44.8	47.6	4.3
Smoked fish has a very sweet taste	0	3.8	7.6	32.4	56.2	4.4
Consuming smoked fish serves as a rich source of nutrient	0	7.6	28.6	22.9	41.0	4.1
Smoked fish gives a better quality	0	7.6	25.7	30.5	36.2	4.1
Smoked fish has a longer shelf	0	13.3	15.2	32.4	39.0	4.0
Smoked fish has a very nice colour	0	11.4	24.8	27.6	36.2	4.1

Source: Field survey, 2022. SD: Strongly Disagree, D: Disagree, U: Undecided, A: Agree, SA: Strongly Agree

Perception of consumers about smoked fish

Table 3 shows the perception of consumers about smoked fish in the study area. The result revealed that less than half (47.6%) of the respondents perceived smoked fish to give a better aroma to food. As regards taste, about 56.2% of the fish consumers strongly agreed that smoked fish has a very sweet taste,

while only 41.0% of the respondents perceive smoked fish as a rich source of nutrients. Meanwhile, 36.2%, 39% and 36.2% of the smoked fish consumers were of the opinion that smoked fish gives a better quality, longer shelf and has a very nice color respectively. These findings are consistent with Adeola *et al.* (2016) and Nsoaga *et al.* (2021) who reported

that consumers perceive smoked fish to have a sweet taste, color, texture, aroma, quality, rich source of nutrient and odor.

Sources of consumers' information about PAHs contaminants in smoked fish

Table 4 shows the various sources of consumers' information about the presence of PAHs and other contaminants in smoked fish in the study area. The results revealed that about 45.7% of the respondents got their information from the internet, family and friends (45.2%), radio (25%), nutritional campaign (18.9%), television (18%), health organization (15.2%), news print (5%) and workshop (2%). This implies that social media served mostly as a medium of creating public awareness about food safety for the respondents in the study area. However, this finding contradicts the findings of (Agbontale *et al.,* 2020) who reported that majority (31.4%) of the respondents sourced their information about the safety of smoked fish from friends and family.

TABLE 4
Distribution of respondents by their sources of information

Sources of Information	Yes (%)	No (%)
Health Organization	15.2	84.8
Radio	25.0	75.0
Television	18.0	82.0
News Print	5.0	95.0
Family And Friend	45.2	54.8
Nutritional Campaign	18.9	81.9
Internet	45.7	54.3
Workshop	2.0	98.0

Source: Field survey, 2022

TABLE 5
Parameter estimates of logit regression for smoked fish

Variables	Coefficients	Standard error	Z	P > |z|
Age	0.10371***	0.03919	2.65	0.008
Gender	-3.13372***	1.17557	-2.67	0.008
Income	0.00001***	3.37e-06	2.99	0.003
Household size	0.64563**	0.29271	2.21	0.027
Marital status	2.36705***	0.75840	3.21	0.002
Education	0.64365**	0.30493	2.11	0.035
Taste	0.34286**	0.13441	2.55	0.989
Aroma	3.17559*	1.76279	1.80	0.072
Nutrients	0.31228	0.61323	0.01	0.992
Constant	2.80969	1.97054	1.43	0.154
Likelihood	-24.6178			

Source: Field survey, 2022

Factors influencing the consumption of smoked fish

Table 5 shows the results of the logit regression analysis in determining the factors influencing the consumption of smoked fish among the consumers in the study area. The likelihood ratio (LR) is statistically significant at a 1% level, indicating that the explanatory variables jointly exert influence on the consumption of smoked fish by the respondents. The result also revealed that coefficients of the variables such as age, gender, income, household size, education, taste, and aroma of smoked fish were significant in influencing the smoked fish consumption in the study area.

The coefficient of age was positive and significant at a 1% probability level. This means that as the consumer gets older the

chance of consuming smoked fish increases. This may be due to the fact that older people are more conscious about their health and are aware of some of the nutritional benefits that they may derive from consuming smoked fish. The findings of this study contradict (Onyeneke *et al.,* 2020) who reported that the age of the consumer significantly decreased demand for smoked fish consumption. Gender also significantly influenced household consumption of smoked fish at a 1% probability level. The negative sign on the coefficients of the gender implies that female consumers prefer smoked fish compared to their male counterparts. This could be due to the fact that women are the ones making purchases of food items in the market and as such may prefer buying smoked fish due to its taste, aroma, and long shelf life. Household size was significant at a 1% level of probability for smoked fish. It can be interpreted that a positive household coefficient means that a person's increase in family size will likely increase their consumption of smoked fish due to affordability compared to other sources of protein. The result also showed that income was significant at a 1% level of probability. This implies that as the income of the household increases, there is a higher probability of increasing their household consumption of smoked fish. This could be attributed to their preference for smoked fish in terms of taste, quality, nutrients, and aroma. This finding is in line with Adeola *et al. (*2016) and Onyeneke. (2020), who stated that household size and income can significantly increase the demand for dried and smoked fish in their respective studies.

Education was positive and significant at a 5% probability level. This implies that at a higher level of education, more smoked fish is consumed among the consumers in the study area. This may be due to the fact that educated households are enlightened about the nutritional benefits associated with consuming smoked fish and are thus willing to consume more. This study agrees with (Ali-ud-din & Ahmad, 2014) who stated that an increase in the level of education had a positive influence on fish consumption. However other studies such as Gebrezgabher *et al.* (2015) and Adeola *et al.* (2016), have established a negative relationship between higher educational level and fish consumption; attributing it to the fact that higher level of education beyond secondary school may shift consumption away towards consumption of other safer protein sources. Furthermore, perception indicators such as the taste and aroma of smoked fish positively influenced its consumption at 10% and 5% levels respectively. This implies that sensory attributes such as sweet taste and aroma attributed to smoked fish can motivate its consumers to purchase it.

Conclusion and Recommendation

From this study, it can be concluded that awareness of polycyclic aromatic hydrocarbons (PAHs) and other contaminants present in smoked fish which are capable of causing various health conditions such as cancer, diarrhea, kidney damage, urinary tract infections, pneumonia, and other related diseases in man was low. Also, factors such as age, gender, income, household size and education significantly influence the consumption of smoked fish among the respondents in the study area.

Furthermore, the perception of consumers such as the taste and aroma of smoked fish also influenced its consumption in the study area. There should be massive

awareness by governments, extension agents, social media, and other relevant stakeholders to enlighten the public on the presence of PAHs and other contaminants in smoked fish. The government should also provide improved smoking ovens at a subsidized rate for the fish processors as this will help to improve the quality of fish being produced for public consumption.

REFERENCES

Adel, N., Mantawy, E.M., El-Sherbiny, D.A. & El-Demerdash, E. (2019) Iron chelation by deferasirox confers protection against concanavalin A-induced liver fibrosis: A mechanistic approach. *Toxicology and Applied Pharmacology*, **382**, 114–148. 10.1016/j.taap.2019.114748 [PubMed] [CrossRef] [Google Scholar].

Adelaja, A.O., Olaoye, O.J, Ikemweiwe, N.B. & Ashley-Dejo, S.S. (2013) Comparison of Microbiological Load Associated with Smoked Fish (Chrysichthys nigrodigitatus) in Ogun State, Nigeria. *Global Journal of Science Frontier Research Agriculture and Veterinary*, **13**(8), 38–37.

Adeola, A.A., Ayegbokiki, A.O., Akerele, D., Adeniyi, B.T. & Bamidele, N.A. (2016) Marketing perspective of smoked catfish by consumers in South-West Nigeria. *Applied Tropical Agriculture*, **21**(2), 58–66.

Adeyeye, S.A.O., Oyewole, O.B., Obadina, A.O., Omemu, A.M., Oyedele, H.A. & Adeogun, S.O. (2015) Socio-economic characteristics of traditional fish processors in Lagos State, Nigeria. *International Journal of Aquaculture*, **5**(37), 1–6.

Adeyeye, S.A.O. & Oyewole, O.B. (2016) An overview of traditional fish smoking in Africa. *Journal of Culinary Science & Technology*, **14**(3), 198–215. http//dx.doi.org/10.1080/15428052.2015.1102785.

Agbontale, A.O., Okorafor, P.U., Ogbu, U.M., Isegbe, E.I. & Adisa, T.A. (2020) Consumers' perception on indigenous spiced smoked catfish (clarias gariepinus) among households in Oyo State. *International Journal of Innovative Agriculture & Biology Research,* **8**(1), 7–14. ISSN: 2354–2934.

Alabi, O.T., Olaoye, O.J., George, F.O.A., Adeola, A.A., Alabi, J.O. & Ojebiyi, W.G. (2020) Awareness and adoption levels of improved smoking oven among fish processors in Lagos Lagoon, Nigeria. *Ghana Journal of Agriculture. Sciences*, **55**(2), 39–58.

Ali-ud-din Khan, M. & Ahmad, I. (2014) An Empirical study into the relation of income and consumption using cross-sectional data, ASEE 2014 Zone I Conference, April 3–5, University of Bridgeport, Bridgeport, CT, USA.

Ayeola, A.A., George, F.O.A., Obasa, S.O. & Sanni, L.O. (2011) Effect of post-slaughter time intervals on the quality of the African catfish, Clarias gariepinus (Burchell, 1822). *American Journal of Food Technology*, **6**(9), 790–797.

Elfredah, K.G., (2022) Climate Change Is Dwindling Fish Catch in Nigeria, Alters Fishers' Sea Level Forecast.

Essumang, D.K., Dodoo, D.K. & Adjei, J.K. (2012) Polycyclic aromatic hydrocarbon (PAH) contamination in smoke-cured fish products. J. *Food Composition and Analysis*, **27**, 128–138.

FAO (2020). La situation mondiale des pêches et del'aquaculture. La durabilitéen action. Food and Agricultural Organisation; English Translation: The Global Situation of Fisheries and Aquaculture. Sustainability in Action. Rome, Italy. Pp. 227.

FES (2021) Fish Smokers and Polycyclic Aromatic Hydrocarbon (PAH) Risks in Senegal. Food Enterprise Solutions. Available online at: https://agrilinks.org/sites/default/files/media/file/BD4FS-PAH-TLN-20210127.pdf (accessed January 5, 2021).

Gebrezgabher, S.A., Amewu, S. & Amoah, P. (2015) Consumer preference and willingness to pay for fish farmed in treated wastewater in Ghana. Selected paper prepared for presentation at the 2015 AAEA & WAEA Joint Annual Meeting, San Francisco, California, 26–28 July, 2015.

George, F.O.A., Ogbolu A.O., Olaoye, O.J., Obasa, S.O., Idowu, A.A. & Odulate, D.O. (2014) Fish processing techniques in Nigeria: A case study of Ibeju-Lekki Local Government Area, Lagos State. *American Journal of Food Technology*, **9**(6), 302–310.

Greene, W.H. (2000) Econometric Analysis, Prentice Hall Inc., Upper Saddle River, New Jersey.

Issa, F.O., Aderinoye-AbdulWahab, S., Kagbu, J. H. & Adisa, R.A. (2022) Assessment of Aquaculture Development Programmes in Nigeria. *Journal of Agricultural Extension*, **26**(1), 18.

Jira, W., Ziegenhals, K. & Speer, K. (2006) "PAHs in smoked meat products according to EU standards". *Fleischwirtschaft International*, **4**, 11–17.

Kruijssen, F., Tedesco, I., Ward, A.D., Pincus, L.E., Love, D.F. & Thorne-Lyman, A.L. (2020) Loss and waste in fish value chains: A review of the evidence from low and middle-income countries. *Global Food Security. Elsevier*, **26**, 2211–9124. https://doi.org/10.1016/j.gfs.2020.100434.

Mulokozi, D.P., Mmanda, F.P., Onyango, P., Torbjdm, L., Tamatamah, R. & Berg, H. (2020) Rural aquaculture: Assessment of its contribution to household income and farmers' perception in selected districts, Tanzania, *Aquaculture Economics and Management*, DOI:10.1080/13657305.20 20.1725687.

Nsoga, J.V.F., Ndomou, M., Manz, K.J.C., Milong, M.C.S., Nchoutpouen, N.M., Ekwalla, M.R.J., Ndômbôl, N.P.R., Dama, A.R., Ngo Tang, C.D., Youogo, M., Gouado, I. & Tchoumbougnang, F. (2021) Effects of two smoking and storage methods on the sensory and bromatological quality of Ilishaafricana (Bloch. 1759). *International Journal of Fisheries and Aquatic Studies*, **9**(2), 280–284.

Odediran, O.F. & Ojebiyi, W.G. (2017) Awareness and adoption of improved fish processing technologies among fish processors in Lagos State, Nigeria. *Research Journal of Agriculture and Environmental Management*, **6**(3), 46–54.

Olaoye, O.J., Odebiyi, O.C. & Abimbola, O.T. (2015) Occupational hazards and injuries associated with fish processing in Nigeria. *Journal of Aquatic Science*, **3**, 1–5.

Omole, D.O & Longe, E. (2014) Re-aeration coefficient modeling: A Case Study of River Atuwara in Nigeria. https://www.researchgate.net/figure/The-map-of-Ado-Odo-Ota-LGA-showing-river-Atuwara_fig1_266313917.

Onyeneke, R.U., Amadi, M.U., Iheanacho, S.C. Uwazie, U. & Enyoghasim, M.O. (2020) Consumption of different forms of fish in Abakaliki Metropolis of Ebonyi State, Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, **20**(2). ISSN 1684 5374.

Pigott, G.M. (2016) Fish Processing. A Book by Singh RP. Encyclopaedia Britania.

Puke, S. & Galoburda, R. (2020) Factors affecting smoked fish quality: A review. *Research for rural development*, **35**, 132–139.

Ryan, P.C. (2023) *Escherichia coli* (E coli) Infections. Drugs & Diseases; Infectious Diseases. https://emedicine.medscape.com/article/217485-medication?form=fpf. Updated: May, 11, 2023.

Sakyi, E.M., Jia C., Ampofo-Yeboah, A. & Aglago, A. (2019) Fish Smoking in Ghana: A Review. *Journal of Fisheries Sciences*, **13**(3), 13–24.

Shahbandeh, M. (2023) Fish production worldwide 2002–2022.https://www.statista.com/statistics/264577/total-world-fish-production-since.

Shen, M., Chapman, R.S., Xingzhou, H., Lai LZLH, Chen, H. & Lan, Q. (2008) Dietary. Study as supported by the Ministry of Agriculture of Latvia, Grant contract no. 270606/S318.

Tarkan, Ş., Sakine, D. & Mükremin, Ö. (2022) Polycyclic Aromatic Hydrocarbons (PAHs) and Their Importance in Animal Nutrition. DOI: 10.5772/intechopen.101816.