Analysis of Factors Influencing the Adoption of Charcoal-Powered Processing Kiln by Fish Farmers: Evidence from Nigeria

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***Abstract*— *This study assessed the factors influencing the adoption of charcoal-powered kiln in Akure Metropolis, Ondo State. The specific objectives of the study were analysed using descriptive and inferential statistics. Primary data were sourced from 30 fish processors through a snowball sampling technique using a well-structured questionnaire. Data collected for the study were analyzed using descriptive statistics, budgeting techniques and logit model. Results revealed that 76.7% of the fish processors were below 60 years. Most (80.0%) of the sampled farmers were male, 83.3% were married, having a household size of 6-10 persons while more than half (56.7%) of the respondents were educated. The benefit-cost analysis showed that charcoal-powered smoking kiln was found to be profitable. The marginal effects estimated from the logit coefficients showed that years of schooling, household size, income level, shelf life and consumer's taste and preference for the product were positively related to the adoption of charcoal-powered kiln technology. Based on the findings, the study concluded that charcoal-powered smoking kiln is reliable and profitable for fish smoking. It is, therefore, recommended that policy that will enhance and facilitate its adoption should be promoted. Extensive awareness and further training of fish processor through mass media should be carried out and sponsored by both government and non-governmental agencies across the country.*

***Keywords*— Charcoal-powered kiln, Logit model, smoked fish, Nigeria.**

I. INTRODUCTION

Fish occupies a strategic position in Nigerian food basket, contributing immensely to the food security of the country. Fisheries provide employment to over 8.6 million people directly while about 19.6 million people are also indirectly depended on this subsector as their means of livelihoods (World Fish, 2018). Nigerian fishing activities are made up of three sources such as artisanal, industrial and aquaculture. Fish is an important source of protein to a large extent and thus provides 40% of the dietary intake of animal protein for average Nigerian.

About 2.7 million metric tons of fish annually is required to satisfy the dietary needs of Nigerian citizens. However, the aggregate total domestic fish supply from all sources, both from capture and culture fisheries, is about 0.8 million metric tons per annum thereby creating a deficit of 1.9 million tons to fill the demand-supply gap (Emefiele, 2019) cited in Johnson et al. (2020). The gap between demand and supply has raised Nigeria import bill on frozen fish to over $1.2 billion annually (FAO, 2007).

According to Adekoya (2004), fish and fish products constitute more than 60% of the total protein intake in adults especially in rural areas. Fish as food is known to be superior to all terrestrial meats (beef, pork and chicken, etc), rich in animal protein and highly digestible energy.

Fish is suitable for supplementing diets of high carbohydrates contents, good source of thiamine and rich in Omega-3 poly-saturated fatty acids, fat and water soluble vitamins and minerals. It is highly rich in Polyunsaturated Omega III fatty acids, which are important in lowering blood cholesterol level and high blood pressure. It is able to mitigate and alleviate platelet of cholesterol aggregation and various arteriosclerosis conditions in adult populations.

Fish value chain covers production, processing, storage and distribution to the final consumers. Fish processing is an important stage in the handling of fish product. One of the major activities in fishery is post-harvest handling of the fish. This stage requires efficient management and when it is not efficiently handled, it results in losses and low returns to the efforts of fish processors. This has been the situation in Nigeria over the years.

Despite abundance of on-shelf technologies in our various institutions, fish processors are still making use of traditional methods (drums) for fish smoking which produces fish characterized with poor quality and high content of Polycyclic aromatic hydrocarbon (PAH) knowing to be dangerous to public health. Smoking of fresh fish is primarily done to preserve it from spoilage and also to prolong the shelf life of fish products. There are four major ways of smoking fresh fish namely sun drying, salting, smoking, and refrigeration. In Nigeria, traditional smoking is often done in the open air using fuelwood of different kinds. The sun drying and smoking in the open fire are often characterized with dirt, sand and dust (Bolaji, 2005). Open fire smoking makes smoked fish prone to external contamination and thus extends the length of time spends on fish smoking and sometimes it is destroyed by rain and strong wind (Bomfeh, et al., 2019). This method is not only laborious but also constitutes environmental hazards to the society. The use of traditional techniques take longer drying time and product-quality is difficult to control. Traditional methods of smoking fish can cause eye and skin irritations to fish processors.

There are several improved fish processing technologies suggested in the literature, among them include charcoal and gas powered kilns. Both technologies are reported to have very close time range for drying fish and low PAH (Okusanya et al. 2021). However, in the literature, charcoal-powered kiln technique for smoking fish is found to be more likely cost-effective compared to the cost of gas-powered kiln in the study area.

Scientifically, findings showed that several smoking methods have been designed and suggested to be used in order to bring down the content of polycyclic aromatic hydrocarbon on smoked fish. PAH recommended limits by European Union are yet to be met in developing countries, Nigeria inclusive. However, the adoption of improved smoking techniques has a lot of challenges due to several perceptions towards these technologies. Perception of cost and profitability associated with the technology, compatibility, and some other socio-cultural constrains preventing fish farmers from using the technologies.

Most available studies are related to technical aspects of smoking techniques, but factors constraining the utilization of improved technologies on fish smoking are still grossly inadequate if not lacking, thus this study is conceptualized to fill the knowledge gap. This study therefore seeks to provide answers to the following questions. What are the socio-economic characteristics of the respondents ?; and What are the factors affecting the adoption of charcoal-powered fish smoking? Therefore, the findings from this study would assist government to make the necessary polices that will help accelerate the utilization of modern method of smoking fish.

II. LITERATURE REVIEW

Traditional smoking and sun drying of fish are common methods of fish preservation in Nigeria. In the process, moisture content present in the fish is extracted through heating, thereby inhibiting the action of micro-organisms and prolong their shelf life (Amoo *et al.*, 2007; Singh and Heldman, 2013; Pigott, 2015). These methods are employed probably due to irregular supply of or lack of access to electricity to preserve and or process their products. Bolaji (2005) reported that despite the rudimentary nature of traditional processing methods, the lack of control over the drying rate, sometimes results to under- or over-drying and expose fish to wind, dust, dirt, insect infestation and contaminants such as flies. The quality of fish declines if not properly processed after harvesting and thus affecting consumer's preference (Sen, 2005). Different processing techniques of fish produce different output that suits consumers taste.

However, different processing techniques produce different physical and chemical properties that may or may not produce the qualities consumers are actually looking for in smoked fish. Limited studies exist in the economic literature on adoption of fish smoking technologies. Some of the few include, Bolorunduro et al. (2005) who investigated adoption of improved fish preservative technologies in North-western, Nigeria. They found years of experience, extension contact, access to credit, age, education, and acquisition cost as factors that are positively affecting adoption of chokor, Burkinabe and Altona kiln in their study area. From technical perspective, Okusanya et al. (2021) also investigated the impact of improved smoking kiln design on hygiene and timeliness of drying of smoked fish in Nigeria. They reported that both charcoal and gas-powered kiln produced smoked fish that were hygienic and not likely to exceed maximum limits of PAH allowed by the United States Environmental Protection Agency.

Ajang et al. (2010) used cost-benefit analysis to evaluate the performance of chorkor smoker in smoking fresh fish in Nigeria. The study found that chorkor smoker was proved to have superior qualities over traditional methods of smoking fish product. Chorkor smoker also gives higher economic returns compared to traditional methods. Study by Akinola et al. (2006) compared traditional and solar fish drying systems towards enhancing storage and preservation in Nigeria. The study concluded that solar drying system eliminates the contact between fish and flies.

Odediran and Ojebiyi, 2017 assessed the awareness and adoption of improved fish processing technologies among fish processors in Lagos State. The study found that drum and mud oven were common techniques employed by the people in their study area. Nti (2002) used participatory appraisal approach to evaluate the determinants for effective adoption of an improved fish-processing technology in Ghana. They found that 88% of the processors completely adopted improved technology and reduced drudgery of fish-smoking activity, however, the key limiting factors were reported as lack of finance, high cost and non-availability of input and inability for group formation. Hassan et al. (2020) used logit regression and propensity score matching to evaluate the impact of adoption of modified drum-oven technology on income of fish processors in Niger State. The study found that age, sex, processed output and affordability had positive influence on the adoption of modified drum-oven technology (MDOT). Result revealed that adoption of MDOT increased average output by 1.008kg.

III. MATERIALS AND METHODS

3.1 Study area

The study was conducted in Ondo State, Nigeria. The state is bounded in the west by Osun and Ogun States and in the north by Ekiti and Kogi States. Ondo State shares boundaries with Edo and Delta States in the east and in the south by the Atlantic Ocean. The State lies between latitudes 5º 45´ and 8º 15´ north of the equator and longitude 4º 30´ and 6º 60´ east of the Greenwich Meridian. Ondo State has eighteen (18) Local Government Areas with an estimated population of about 3.4 million inhabitants (National Population Commission [NPC], 2006). There are two distinct seasons which are the rainy season (April to October) and the dry season (November to March). Though, there is usually an August break for a period of two weeks. The annual rainfall varies from 1,150mm to 2,000mm. Ondo State riverine area is a veritable ground for fishing.

A multi stage sampling procedure was used to select fish processors. At a start, dual smoking kiln (using both charcoal and gas) was fabricated with locally sourced materials such as aluminum plates to coat both the interior and exterior of the kiln. The second stage involved snowball sampling of thirty (30) fish farmers who are into production only.

In the third stage, 50 kg of fresh fish (*Clarias gariepinus*) was purchased from local markets. The fishes were slaughtered and non- edible parts such as gills were removed and thoroughly washed to remove sand as well in order to achieve good hygiene. Little quantity of table salt and seasonings were added to enhance its taste. In the fourth stage, we placed the fishes in the oven for drying using both charcoal and gas as sources of energy. In the final stage, group method of teaching and result demonstrations were employed to train the farmers using these improved methods of smoking.

3.2 Analytical Techniques

Data collected were analyzed using descriptive and inferential statistics. The descriptive statistics used were frequency count, tables, percentage distribution. Budgeting analysis was used to evaluate the profitability of using charcoal-powered kiln to smoke fresh fish while binary logistic regression was used to identify factors influencing the adoption of charcoal-powered smoking kiln by the respondents.

3.2.1 Budgeting Analysis

Budgeting analysis is a technique used to compute cost and returns of enterprises. In this case, we used gross margin to evaluate the profitability of using charcoal and charcoal-powered smoking technique. Mathematically, the gross margins of using both techniques are expressed as follows:

$$GM_i = TR_i - TVC_i \quad (1)$$

$$NP_i = GM_i - D_i \tag{2}$$

Where;

GM_i is the gross margin realised by farmer (₦).

TR_j= Total Revenue realized from charcoal powered kiln by jth farmer (₦)

TVC_j = Total variable cost incurred from charcoal-powered kiln by jth farmer (₦)

NPi = Net profit accrued to i^{th} farmers (₦)

D = Depreciation cost on fixed items

Depreciation for the fixed variables used by fish processor was calculated using equation 3.

$$\text{Depreciation} = \frac{\text{Original cost} - \text{Salvage value}}{\text{useful life}} \tag{3}$$

Profitability Ratios

The profitability of investing on charcoal-powered kiln is evaluated by using following ratios

$$\text{Benefit} - \text{Cost ratio (BCR)} = \frac{\text{Total Revenue}}{\text{Total Cost}} \tag{4}$$

$$\text{Gross ratio (GR)} = \frac{\text{Total cost}}{\text{Total revenue}} \tag{5}$$

$$\text{Rate of Return (ROR)} = \frac{\text{Total cost}}{\text{Total revenue}} \tag{6}$$

3.2.2 Binary Logistic Regression

Binary logit model is a popular econometric tool in adoption related studies. Several studies have used this model to identify factors affecting adoption when the dependent variable is dichotomous (i.e adopter or non-adopter).

Following Guajarati (2003), binary logistic regression model can be expressed as

$$\ln\left(\frac{P_i}{1-P_i}\right) = Z^*{}_i = \frac{1}{(1 + exp^{(\beta_0 + \beta_i X_i)}} \tag{7}$$

Z_i* = Latent dependent variable

In(P_i/1-P_i) = Log of odds ratio of adopter/non-adopter.

P_i = Probability of utilising charcoal-powered kiln by i^{th} fish processor

1-P_i = Probability of not utilising charcoal-powered kiln by i^{th} fish processor

X_i = Row vector of fish processor and technology characteristics

β_i = Column vector of unknown parameters to be estimated,

β_0=constant,

Linearizing equation 7, the reduced equation becomes:

$$Z^*{}_i = \beta_0 + \sum_{i=1}^{J} \beta_0 + \beta_j X_i + \varepsilon_i \begin{Bmatrix} if\, J > 0, Z^*{}_i = 1 \\ otherwise\, Z^*{}_i = 0 \end{Bmatrix} \tag{8}$$

ε_i = Vector of unobserved random effect.

TABLE 1
VARIABLES USED IN THE MODEL

Variable	Description	Measurement	Hypothesized sign
Z_i	Dependent variable	Charcoal-powered smoking kiln = 1, 0 otherwise	
	Explanatory variables		
	Age category		
X_1	31-40	Dummy, If yes-1, 0 otherwise	-
X_2	41-50	Dummy, If yes =1, 0 otherwise	-
X_3	51-60	Dummy, If yes =1, 0 otherwise	-
X_4	>60	Dummy, If yes =1, 0 otherwise	-
X_5	Years of schooling	Continuous, Years spent in schooling	+
	Income category	Dummy, If yes-1, 0 otherwise	
X_6	30001-40,000	Dummy, If yes-1, 0 otherwise	+
X_7	40,001-50,000	Dummy, If yes-1, 0 otherwise	+
X_8	50,001-60,000	Dummy, If yes-1, 0 otherwise	+
X_9	>60,000	Dummy, If yes-1, 0 otherwise	+
X_{10}	Average cost of material	Continuous, measured in ₦	-
X_{11}	Family size	Number of family members	+
X_{12}	Average cost of fish	Continuous, measured in ₦	-
X_{13}	Shelf life	Lasting = 0, 0 otherwise.	+
X_{14}	Taste preference	Satisfactory =1, 0 otherwise	+/-

IV. RESULTS AND DISCUSSION

4.1 Socio-economic characteristics of respondents

The socioeconomic characteristics of the farmers that were analyzed included age, gender, level of education, marital status, pond size, household size and income.

The distribution of respondents' socioeconomic characteristics is presented in Table 2. Majority of the farmers (80.0%) were males while 20.0% were females, suggesting that both male and females are involved in fish processing in the study area. This negates a similar study by Akangbe (2012) who stated in his report that majority of fish processors are women and that the dominance of women is attributed to the fact that women bear primary responsibilities for household sustenance and well-being.

The age structure showed that 40% were between the age of 31 and 40 years, and 40% of the sample farmers were within 50 years of age. This implies that the fish processors in the study area are young and active to cope with the stress of fish processing. Result also showed that many (83.3%) of the processors were married which implies that most of the respondents were mature and responsible to cater for their households. About 43.3% of the fish processors had no formal school education, 20.0% had primary education, 16.7% had secondary school education while 20.0% acquired tertiary education. Okunlola *et al*. (2011) and Agbamu (2006) stated that educational level is one of the factors that influence adoption of new technology by farmers. Educational level of the respondent is an important factor to be considered in adoption of innovation. It was also revealed that half (50%) of the farmers have household sizes of 6-10

TABLE 2
SUMMARY OF SOCIO-ECONOMIC CHARACTERISTICS

Characteristics	Frequency	Percentage (%)
Sex		
Male	24	80.0
Female	06	20.0
Age category		
31-40	02	33.3
41-50	10	6.7
51-60	11	36.7
>60	07	23.3
Marital status		
Single	05	16.7
Married	25	83.3
Educational status		
No formal education	13	43.3
Primary education	06	20.0
Secondary education	05	16.7
Tertiary education	06	20.0
Household size		
1-5	13	43.3
6-10	15	50.0
>11	02	6.7

Source: Field survey, 2021

4.2 Cost and Returns of 50kg of Smoked Fish/Month

As revealed from Table 3, the cost of purchase of fish (50kg) was ₦212,500.00 per 5cycles/month. Thus, this cost represents about 86.8% of the total variable cost incurred on 50kg of fish smoked for the period. The cost of salt and labor incurred for processing was ₦1000 and ₦7,500, respectively and thus accounted for about 3.5% of the total variable cost (TVC).

Similarly, the cost of charcoal, *Potash alum* and 50 litre of water used accounted for about 8.5% of the total variable cost of processing 50kg of smoked fish by the respondents. The result shows that variable cost for the smoking of fish gulps as much as ₦243, 250 representing about 99.4% of the total cost required to process fresh fish into smoked fish. The depreciation cost on kiln acquired was just N1, 500 with 0.6% of total cost (TC).

From the cost and returns Table, the revenue accrued to a processor was about N375,000 per 5 cycles in a month with a gross margin being ₦133,250 and net profit of ₦131,750. These values indicate that smoked fish business is profitable in the study area.

The profitability ratio conducted on the cost and returns of smoked fish using charcoal show that benefit-cost ratio 1.54. This value implies that for every ₦1 invested in the business, a gain of 54kobo would be accrued. This value shows that the processing technique is profitable and viable. This result agrees with the finding of Olutumise (2020) who reported a high profitability of catfish processors using improved processing techniques in the study area.

TABLE 3
COST AND RETURNS OF 50KG OF SMOKED FISH/MONTH

Charcoal-Powered Kiln		
Variables	**Mean/month (N)**	**%**
Cost of fish (50Kg)	212,500	86.8
Cost of salt	1,000	0.4
Cost of labor	7,500	3.1
Cost of Charcoal (1 bag)	20,000	8.2
Cost of kerosene	1,500	0.6
Cost of alum	250	0.1
Cost of water (50 litre)	500	0.2
Total Variable Cost	243,250	99.4
(TFC) Depreciation on kiln	1,500	0.6
TC= TFC+TVC	244,750	100
Total Revenue = Unit price x quantity sold (5cycles/month)	375,000	
Gross Margin (GM)= TR-TVC	131,750	
NP=TR-TC	130,250	
Benefit-Cost ratio = TR/TC	1.54	
Gross ratio = TC/TR	0.65	

Source; Field survey, 2021

4.3 Factors influencing the adoption of charcoal-powered smoking technique

The coefficients and odd ratios estimated from binary logistic regression are presented in Table 4. The explanatory power of the model was diagnosed using the log likelihood ratio, F-statistics value and Pseudo R^2. The log likelihood ratio was valid, F-statistic of 40.7 showed that all explanatory variables were significant at probability level of 1%. The discussion of the results was based on the marginal effect estimated from logit coefficients because the parameter estimates of logit model cannot be interpreted directly (Gujarati, 2003). As shown in Table 4, out of seventeen (17) variables postulated, fourteen were statistically significantly different from zero at 1%, 5% and 10%, respectively.

4.3.1 Age of respondent

The respondent whose age ranged between 41 and 50years had a negative but significant influence on the adoption of charcoal-powered kiln at the 1% level. The corresponding odd ratio (0.06) is less than one which implies that a one year increase in the age of the adopter, the odds of adopting a charcoal-powered kiln for fish smoking will be lesser than the odds of a non-adopter, ceteris paribus. Similarly, a farmer who is between the ages of 51-60years had a negative influence on the adoption charcoal-powered smoking technique, but statistically significant at the 1% level. This result implies that farmers who are between the ages of 51-60years will be less likely to adopt charcoal-powered compared to a non-adopter. Farmer whose age is greater than 60 years will be less likely to adopt. The finding here negates the findings of Hassan et al. (2020) that age of the processor increases the probability of adoption.

4.3.2 Education of respondents

Education of respondents matters a lot in adoption of technologies because it creates awareness and takes away ignorance (Adetarami, et al. 2020). Ability to read and write makes it easy to scrutinize and weigh future benefits associated with charcoal-powered smoking kiln. Education of the farmers was measured as continuous variable here and the result showed that education had a positive and significant impact at 10% probability level. The corresponding odd ratio of 12.94 is greater than one and thereby suggesting that a one year increase in schooling, *ceteris paribus*, the odds of adopting charcoal-powered kiln for smoking fresh fish will increase by 94% compared to the odds of a non-adopter.

4.3.3 Level of Income of respondents

Income level of the farmer was positively significant at 5% level. The corresponding odd ratios were 3.74 and 17.81 respectively. The results imply that a unit increase in farmer' income, the odds of using charcoal-powered kiln will increase by 3.74 and 17.81 times compared to the odd of a non-user. The finding is in consonant with Hassan et al. (2020) that income of the processor increases the probability of adoption.

4.3.4 Household size

Household size is positively and significantly related to the adoption of charcoal-powered kiln as expected. This implies that an additional member in the family, farmer will be more likely to adopt charcoal-powered kiln compared to a non-adopter of this technology. The coefficient of household size is 0.19 and the corresponding odds ratio of 1.29 is greater than one. The positive sign for this variable has theoretical agreement with the study hypothesized sign. Thus, it implies that a farmer with large family is more likely to adopt charcoal-powered kiln compared to the base category. The result indicates that increasing household size by a unit, *ceteris paribus*, the odds of adopting charcoal-powered kiln will increase by 29%.

4.3.5 Average cost of materials, Fish and Labour

Also significant are average cost of materials, fish and labour. The coefficients for these variables are negative as expected and the corresponding odd ratios are less than one which indicates that a 1% increase in these variables will cause the odds of using charcoal-powered kiln to reduce by 6%, 48%, and 18%, respectively, compared to the odds of a non-user.

4.3.6 Taste preference

Consumer's taste and preference is positively related to the adoption of charcoal-powered kiln. The corresponding odd ratio is also greater than one meaning that the odds of using charcoal-powered kiln will increase by 34% compared to the odds of a non-adopter.

4.3.7 Shelf life

A long Shelf life for fish is expected to enhance its attractiveness and thereby increase the demand for smoked fish. The results show that the variable is positive and significantly related to adoption of technology at 5% level of probability. The positive association with the adoption of charcoal-powered kiln is expected because fish smoking promotes market value of the product. Therefore, a reduction in the water content of fish prolong the shelf life of the fish, Similarly, consumer demand for the smoked fish using a charcoal-powered kiln will lead to higher sales compared to sales of non-adopter.

TABLE 4
RESULTS OF LOGIT MODEL FOR THE ADOPTION OF CHARCOAL-POWERED SMOKING KILN

Variable	Description	Coeff.(sd.err)	Marginal effect
	Age category		
X_1	31-40	-0.23(0.60)	0.79
X_2	41-50	-2.85** (0.98)	0.06
X_3	51-60	-2.96**(1.22)	0.05
X_4	>60	-2.96**(1.46)	0.05
X_5	Years spent in schooling	2.56*1.51)	12.94
	Income category		
X_6	30001-40,000	1.37**(0.60)	3.94
X_7	40,001-50,000	0.93(0.57)	2.53
X_8	50,001-60,000	1.47**(0.73)	4.35
X_9	>60,000	2.88*(1 49)	17.81
X_{10}	Average cost of material	-2.09***(0 58)	0.06
X_{11}	Household size	0.19**(0.09)	1.29
X_{12}	Average cost of fish	-0.74**0.33)	0.48
X_{14}	Texture	1.38***(0.43)	3.97
X_{15}	Shelf life	1.08***(0 06)	2.94
X_{16}	Taste preference	0.85**(0.34)	2.34

Log likelihood ratio= 58.81, LRCH= 40.67, Prob>chi$_2$ = 0.00, R^2 = 0.2
Source: Field survey, 2021.

V. CONCLUSION AND RECOMMENDATIONS

The study, specifically, evaluated profitability of smoked fish using a charcoal-powered smoking kiln as well as identified the determinants of adoption of charcoal-powered kiln in the study area. Primary data were sourced from 60 fish processors through a snowball sampling technique using a well-structured questionnaire. The study concluded 76.7% of the fish processors were below 60 years. Majority (80.0%) of the farmers were male-headed households dominated fish processor, 83.3% were married with more than half of them (56.7%) were educated. Charcoal-powered smoking kiln was found to be profitable. The marginal effects estimated from the logit coefficients showed that years of schooling, household size, income level and shelf life of the smoked fish were positively related to the adoption of charcoal-powered kiln compared to a non-adopter.

Based on the findings, the study concluded that charcoal-powered smoking kiln technology is profitable for fish smoking. It is therefore, recommended that policy that will enhance and facilitate its adoption should be encouraged among the farmers. Extensive awareness through mass media should be carried out and sponsored by both government and non-governmental agencies across the country.

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